5882

JOURNAL

OF THE

INSTITUTION OF
ELECTRICAL ENGINEERS,

INCLUDING

ORIGINAL COMMUNICATIONS ON TELEGRAPHY AND
ELECTRICAL SCIENCE.

PUBLISHED UNDER THE SUPERVISION OF THE EDITING COMMITTEE
AND EDITED BY
G. C. LLOYD, SECRETARY.

VOL. 34. 1904–1905.

London:
E. AND F. N. SPON, LIMITED, 57, HAYMARKET, S.W.
New York:
SPON AND CHAMBERLAIN, 123, LIBERTY STREET.

1905.

ELECTIONS.

Member.

Charles L. Edgar.

Associate Members.

James Askew.
William Briggs.
Joseph Wilfred Hadfield.
David Huntley.
James Samson Morton.
George Reginald J. Parkins
John Sedgwick Peck.

Students.

Henry Raper Ainsley.
Ernest Barraclough.
Kenneth Dudley Bullpitt.
John Arthur Cook.
Harry Corney.
Thomas Carey Dunne.
Alexander Victor Ferguson.
Herbert Owen Michael Gammon.
Charles Edgar Garratt.
Ernest William Heathcote.
Leslie Barnett Hewitt.
Clifford Hobson.
Robert Henry F. Houstoun.
Henry Thomas Jager.
Robert Donaldson Jenner.
Donald Knowles.
Thomas Saumarez Lacy.
Alfred William Lambourne.
William Thomas Massey.
Max Mercer.
Ernest R. Myers.
Herbert Pearce.
Thomas Sylvanus Pipe.
William Arthur Pitts.
William Rodger.
John Ernest Roberts.
Howard Mark William Roy
Frederick Clifton Russell.
Charles Ernest Savage.
R. Savarimathen.
Robert Shaw.
Thomas Mountford Taylor.
Thomas L. B. Westerdale.

Donations to the *Library* were announced as having been rec since the last meeting from Messrs. L. Andrews, A. Artom, *Electrical Review;* to the *Building Fund* from Messrs. R. H. Bu R. Livingstone, J. C. Smail, L. C. B. Trimnell; and to the *Ben Fund* from Messrs. G. D. Gibson, R. W. Hughman, S. Insull, Manton, A. Wyllie, to whom the thanks of the meeting were accorded.

The discussion on Mr. Addenbrooke's paper was concluded page 532), and the following paper was then read.

The meeting adjourned at 9.30 p.m.

SETTING TYPE BY TELEGRAPH.

By DONALD MURRAY, M.A. (Sydney).

(Paper read February 23rd, 1905.)

Any person who has had occasion to examine the records of patents ected with telegraphy, must have been astonished at the number printing telegraphs invented during the past sixty years. In the ed States alone over four hundred printing telegraph patents have issued since the invention of the electric telegraph. These patents race about 150 distinct printing telegraph instruments or systems; yet, with the exception of the stock-tickers and the Hughes ting telegraph, it is only within recent years that two or three y successful machines have emerged. In hardly any other field of an endeavour has so much labour resulted in so little return. e are many reasons for this want of success; but they are all to the extreme complexity of the conditions to be fulfilled, and absence of any technical literature explaining what these condiare. With one or two exceptions, telegraph engineers, realising difficulties of the subject, have left it alone, and printing telegraph tors have, in most cases, been outsiders. In fact the whole of the lems connected with the handling of type, including typewriters, setting, type-casting, and similar machines, have proved very ctory, and the best solutions have often come from outsiders, who stepped in where experts feared to tread, and have in this way dered into unexpected success. The complexities culminate in the ting telegraph, because in that case the problem is to set type at a ce. The type may be fixed on the circumference of a wheel, or exist as separate type on the ends of type-bars, as in most typers, or as loose type in a type-setting machine; but in all cases the lem is to set type—that is to say, to bring a particular type to a cular printing point in the shortest possible time, and in the case printing telegraph to do that at a distance over a single telegraph

t may be pointed out, in passing, that all telegraph systems, from Morse key upwards, are printing telegraphs more or less developed, that a completely developed telegraph system must be a printing aph. Telegraphy is one of the few branches of human activity ich the tendency to substitute machinery for human skill has not ade much progress; but the advantages to be gained are conble, and there is every indication that the era of fully-developed ne-telegraphy has now arrived. The subject is very large, and it will be necessary to confine attention, in this paper, to the class of printing telegraphs used, or being tried, by telegraph administrations for the transmission of ordinary commercial and press messages. For this class of work the stock-ticker systems are of course unsuitable, their field being the urban distribution of news, with some possibilities as local feeders to the general telegraph system. The Hughes printing telegraph is widely used for general traffic on the Continent of Europe, where about three thousand of these instruments are in service; but the Hughes prints the messages on a tape, and its speed is limited by the manual skill of the operator. For a long time there has existed a need for increased capacity of transmission, printing in page form, reduction in the percentage of errors in transmission, and increased economy of labour. During the last few years there has been a remarkable outburst of activity amongst printing telegraph inventors desirous of meeting these requirements. The Baudot system, widely used in France, dates back to about the year 1880; but the Rowland, the Buckingham, the Murray, and the Siemens and Halske systems are all products of the past four or five years. It is with systems of this kind that this paper proposes to deal.

THE ESSENTIAL FEATURES OF TELEGRAPHY.

If we disregard the small class of telegrams that merely express emotions, the essence of telegraphy is control. When A sends a telegram to B, it promotes or restrains the actions of B, and B frequently reciprocates by controlling the actions of A. Telegraph systems, therefore, belong, not to the class of producing or distributing, but to the class of controlling mechanisms. From the point of view of the theory of machines, the only possible form of controlling mechanism is the lock and key. It is for this reason that telegraph instruments consist almost entirely of ratchet mechanisms, including the complicated permutation locks that form the main feature of all the modern high-speed printing telegraphs. At the transmitting station certain ratchet mechanisms are used to impress permutation patterns on a small stream of energy which flows through the intervening space from the sending to the receiving station. It is these peculiar patterns impressed on the energy stream that operate the permutation locks of the receiving mechanism, and thus subsequently determine the motions of the recipient of the message.

Hence the fundamental feature of printing telegraphy, and therefore of all practical telegraphy, is the kind of patterns or permutations transmitted. In telegraphy these patterns are symbolic. The word, as spoken, has to be broken up into letters, and the letters translated into special telegraphic symbols. On the other hand, the essence of telephony being direct communication, we are forced to use a method preserving the exact form of the word symbols that we habitually use. This results in the employment of excessively complicated patterns or variations of the energy stream, so that about thirty impulses per letter are required in the telephone, as against about four per letter with the Morse alphabet. That is to say, the telephone saves labour by giving direct communication only at the expense of very heavy wire cost. The telegraph, by using the symbolic method of representing letter sounds, effects an immense economy in the number of signals per letter, thereby effecting a great economy of wire, but only at the expense of increased labour cost for translation. It is the object of machine telegraphy not only to increase the saving of telegraph wire still further, but also to reduce the labour cost of translation and writing by the use of suitable machines. The simplicity of these machines and the saving of wire cost depend on the fewness and simplicity of these signals. It is in this reduction in the number and in the simplification of signals that there will be found to lie not only the fundamental distinction between the telegraph and telephone, but also the fundamental criterion of all telegraph systems—What number and what kind of signals per letter do they require? For a given wire, the fewer the signals the more the business that can be passed over it; and for a given amount of business the fewer the signals the cheaper the wire that can be used. And with the increase of distance the cost of the wire becomes all-important. Pupin self-inductance coils are being applied to help the telephone, but they are equally applicable to the telegraph. On the other hand, if we can do without inductance coils so much the better; and the way to achieve that result is to use as few signals per letter as possible. Hence nothing can alter the fundamental criterion—What number and what kind of signals per letter does the system use? And so far as the class of work dealt with by telegraph administrations is concerned, the telegraph systems with the best signals for long-distance work will, in the end, supplant all others.

TELEGRAPH SIGNALLING ALPHABETS.

A little consideration of the facts will show that the codes of signals telegraphic alphabets that meet all the requirements for signalling means of an electric current through a telegraph wire are comparatively few in number. If we first regard the matter from a metaphysical point of view, it will be found that all signals have a Space aspect and a Time aspect. Signals in which the meaning depends the space aspect may be conveniently described as space signals. In broad sense these are telegraphic, and they appeal to the eye. Signals which the meaning depends on the time aspect may be conveniently described as time signals. In the broad sense these are telephonic, appeal to the ear. For instance, a signboard may extend over feet and 100 years; but the intelligence conveyed does not depend the duration of the signboard. It is a space signal. On the other a Morse signal in a wire may extend over half a second and 500. In this case it is the time aspect which is significant. It is a time. In a printing telegraph the space signals forming the written message have to be converted into time signals, in order to be sent the telegraph wire. The wire signals must occupy various positions in time, because, for commercial reasons, the wire cannot occupy positions in space. That is to say, there must be only one wire.

it will be necessary to confine attention, in this paper, to the class of printing telegraphs used, or being tried, by telegraph administrations for the transmission of ordinary commercial and press messages. For this class of work the stock-ticker systems are of course unsuitable, their field being the urban distribution of news, with some possibilities as local feeders to the general telegraph system. The Hughes printing telegraph is widely used for general traffic on the Continent of Europe, where about three thousand of these instruments are in service; but the Hughes prints the messages on a tape, and its speed is limited by the manual skill of the operator. For a long time there has existed a need for increased capacity of transmission, printing in page form, reduction in the percentage of errors in transmission, and increased economy of labour. During the last few years there has been a remarkable outburst of activity amongst printing telegraph inventors desirous of meeting these requirements. The Baudot system, widely used in France, dates back to about the year 1880; but the Rowland, the Buckingham, the Murray, and the Siemens and Halske systems are all products of the past four or five years. It is with systems of this kind that this paper proposes to deal.

THE ESSENTIAL FEATURES OF TELEGRAPHY.

If we disregard the small class of telegrams that merely express emotions, the essence of telegraphy is control. When A sends a telegram to B, it promotes or restrains the actions of B, and B frequently reciprocates by controlling the actions of A. Telegraph systems, therefore, belong, not to the class of producing or distributing, but to the class of controlling mechanisms. From the point of view of the theory of machines, the only possible form of controlling mechanism is the lock and key. It is for this reason that telegraph instruments consist almost entirely of ratchet mechanisms, including the complicated permutation locks that form the main feature of all the modern high-speed printing telegraphs. At the transmitting station certain ratchet mechanisms are used to impress permutation patterns on a small stream of energy which flows through the intervening space from the sending to the receiving station. It is these peculiar patterns impressed on the energy stream that operate the permutation locks of the receiving mechanism, and thus subsequently determine the motions of the recipient of the message.

Hence the fundamental feature of printing telegraphy, and therefore of all practical telegraphy, is the kind of patterns or permutations transmitted. In telegraphy these patterns are symbolic. The word, as spoken, has to be broken up into letters, and the letters translated into special telegraphic symbols. On the other hand, the essence of telephony being direct communication, we are forced to use a method preserving the exact form of the word symbols that we habitually use. This results in the employment of excessively complicated patterns or variations of the energy stream, so that about thirty impulses per letter are required in the telephone, as against about four per letter with the Morse alphabet. That is to say, the telephone saves labour by giving direct communication only at the expense of very heavy wire cost. The telegraph, by using the symbolic method of representing letter sounds, effects an immense economy in the number of signals per letter, thereby effecting a great economy of wire, but only at the expense of increased labour cost for translation. It is the object of machine telegraphy not only to increase the saving of telegraph wire still further, but also to reduce the labour cost of translation and writing by the use of suitable machines. The simplicity of these machines and the saving of wire cost depend on the fewness and simplicity of these signals. It is in this reduction in the number and in the simplification of signals that there will be found to lie not only the fundamental distinction between the telegraph and telephone, but also the fundamental criterion of all telegraph systems—What number and what kind of signals per letter do they require? For a given wire, the fewer the signals the more the business that can be passed over it; and for a given amount of business the fewer the signals the cheaper the wire that can be used. And with the increase of distance the cost of the wire becomes all-important. Pupin self-inductance coils are being applied to help the telephone, but they are equally applicable to the telegraph. On the other hand, if we can do without inductance coils so much the better; and the way to achieve that result is to use as few signals per letter as possible. Hence nothing can alter the fundamental criterion—What number and what kind of signals per letter does the system use? And so far as the class of work dealt with by telegraph administrations is concerned, the telegraph systems with the best signals for long-distance work will, in the end, supplant all others.

TELEGRAPH SIGNALLING ALPHABETS.

A little consideration of the facts will show that the codes of signals or telegraphic alphabets that meet all the requirements for signalling by means of an electric current through a telegraph wire are comparatively few in number. If we first regard the matter from a metaphysical point of view, it will be found that all signals have a Space aspect and a Time aspect. Signals in which the meaning depends on the space aspect may be conveniently described as space signals. In the broad sense these are telegraphic, and they appeal to the eye. Signals in which the meaning depends on the time aspect may be conveniently described as time signals. In the broad sense these are telephonic, and appeal to the ear. For instance, a signboard may extend over [illegible] feet and 100 years; but the intelligence conveyed does not depend on the duration of the signboard. It is a space signal. On the other hand a Morse signal in a wire may extend over half a second and 500 miles. In this case it is the time aspect which is significant. It is a time signal. In a printing telegraph the space signals forming the written message have to be converted into time signals, in order to be sent over the telegraph wire. The wire signals must occupy various positions in time, because, for commercial reasons, the wire cannot occupy various positions in space. That is to say, there must be only one wire.

At the receiving end of the wire the time signals have to be again co
verted into space signals if they are to reach the brain of the recipi
through his eyes, and that is a necessity, because the average citi
does not know Morse. It is the time signals in the wire that it i
so important to economise.

It is not possible in this paper to go fully into all the possib
kinds and best forms of telegraph signals, but the following summar
will be sufficient to preserve the thread of the argument.

Unlike telephonic signals, all telegraphic signals are built up o
of definite units (Morse dots or half-waves). It is not possible t
signal telegraphically by varying the duration of these units. Nor is
desirable to signal by varying the amplitude of the units, as that intr
duces the weakness of the quadruplex. If weakness is to be avoid

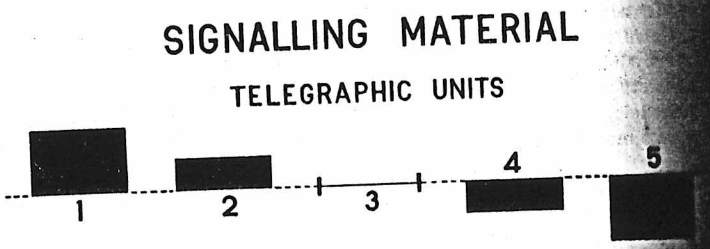


FIG. 1.

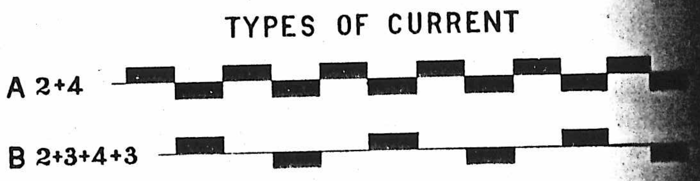


FIG. 2.

the meaning of the signals must not depend on varying amplitu
duration of the units, but only on varying permutations of the
Fig. 1 shows the only units ever used in practical telegraphy.

In regard to units 1 and 5, it is obvious that bad weather is al
a critical time with aërial telegraph wires, and, from a business
of view, a telegraph system employing the quadruplex method o
variations of current strength that can always be relied upon
during bad weather—thereby doubling the trouble—is disas
Two variations of current strength are also undesirable for
ground cables, the inductive trouble between neighbouring
being severe with the strong current needed. Quadruplex ty
current are therefore clearly not suitable for a first-class p

elegraph, and they are useless for any telegraph system that has to
ork over long distances.

As for the zero unit 3, one of the worst evils with which telegraph
ngineers have to contend is the inductive interference between neigh-
bouring wires, leading to the mutilation, and sometimes to the
bliteration of signals. Experience has shown that the best remedy
always to keep sufficient current flowing in the wire to preserve a
ositive or a negative value in spite of the parasitic currents. This at
nce rules out the zero unit on long lines with a number of wires, or in
ultiple-wire cables—that is to say, on busy lines where a printing
legraph would find its chief employment. Thus units 1, 3, and 5 are
cluded, and A (Fig. 2) is the only reliable type of current for a high-
peed printing telegraph on overland lines or multiple-wire cables. It
this type of current that is employed in the Baudot, Murray, Rowland,
nd Buckingham systems, and it is the ordinary "double-current" of
e British telegraph service. This one familiar fact, that alternating
urrent must be used, sweeps into oblivion at least three-fourths of the
inting telegraphs invented during the past sixty years.

For single-wire ocean cables, where there is no inductive trouble
om neighbouring wires, the zero unit can be employed, and as only
ort impulses are permissible, B (Fig. 2) is the only type of current
t is used in ocean-cable work.

There remains the question whether the shape of the signalling
s is important from the point of view of machine telegraphy.
out ten years ago there was a brisk discussion in some of the
ctrical journals in regard to the advantages of the simple harmonic
ve or sine wave for the transmission of power by the alternating
rent. A group of American scientific men, headed by Professor
land, who contended that the sine wave was the best, took it for
nted that the best method of transmitting energy was also the best
thod of transmitting intelligence, and advocated the use of the sine
e in telegraphy. Certainly if Smith wants to make Jones spin
d like a dancing dervish, the best way might be for Smith to trans-
sine waves to Jones; but in practice, Smith always wants to make
s perform an excessively complicated and irregular series of
ions, and for this purpose it is essential to transmit similar motions
introducing upper harmonics in a fragmentary, non-periodic, and
y irregular way. Even if it were possible to signal by means of sine
es, there is against the sine wave arrangement the practical dis-
ntage that special machinery would be required to generate the
waves, and also to repeat them, as an ordinary repeater would at once
them on as square signals. So far as undulatory signals are
erned, there is, of course, nothing to prevent them being applied
y system of machine telegraphy if desired.

and B (Fig. 2) being the sole permissible types of current, it only
ins to build up alphabets or codes of signals by introducing
larities or patterns by various substitutions of units. Space will
ermit of more than a few of the alphabets of practical importance
referred to. The simplest of all these alphabets is that employed
Hughes printing telegraph. It is as follows:—

HUGHES ALPHABET

15 UNITS PER LETTER (AVERAGE)

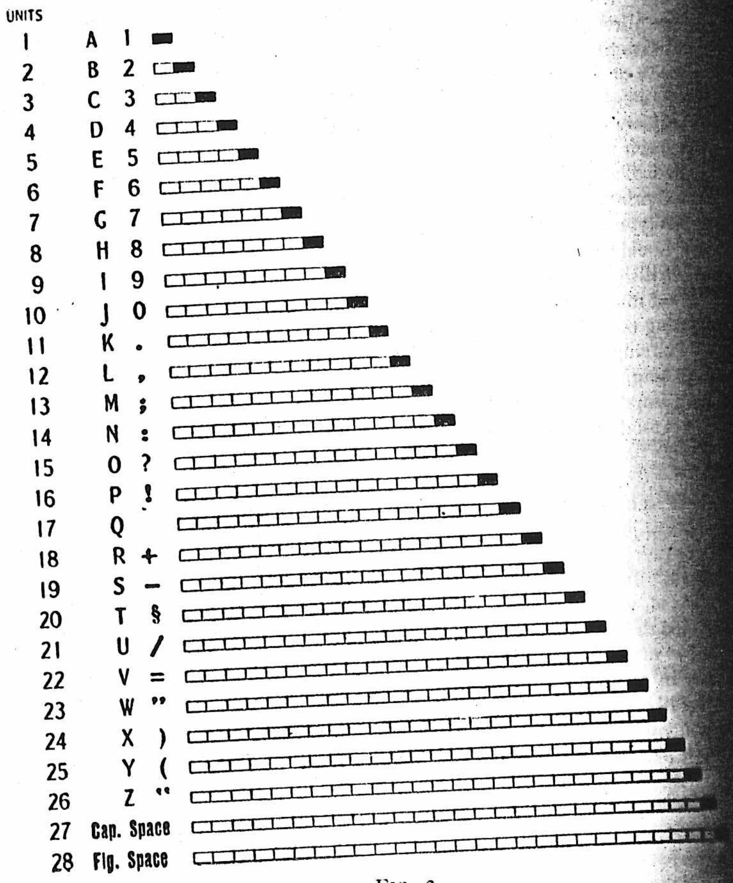


FIG. 3.

On the average there are about 15 units per letter in the H alphabet. There is only one current unit, but there are no less th zero units.

The number of units in the Hughes code can be reduced by positive and negative units—"A," for instance, being a positive unit "B" a negative unit; but the most satisfactory way to reduce the ber of units is to resort to more complex permutations. Perhap simplest alphabet so formed consists of the permutations of tw rent units in eleven different positions, with the proviso that n

than one zero unit must intervene between two current units. This gives forty-five permutations. This alphabet is the basis of the Rowland system, and may, therefore, be appropriately called the Rowland alphabet. It is as follows:—

ROWLAND ALPHABET

12 UNITS PER LETTER

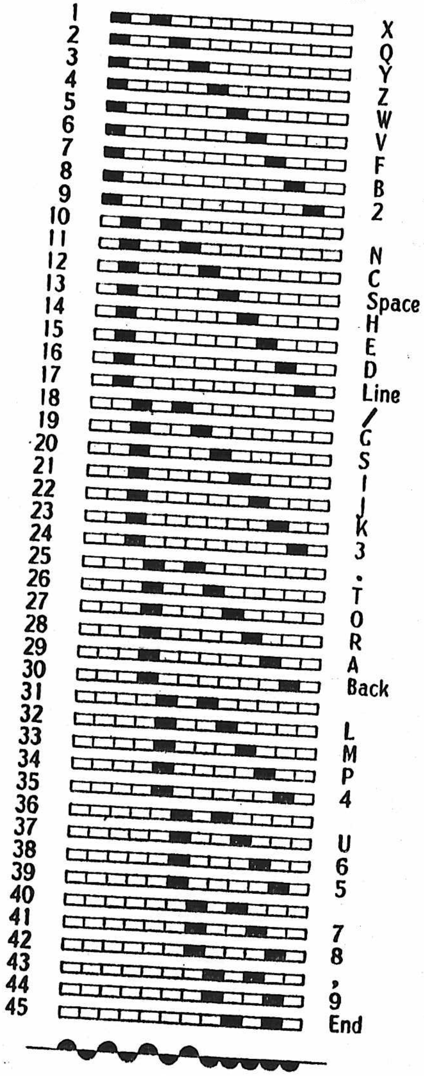
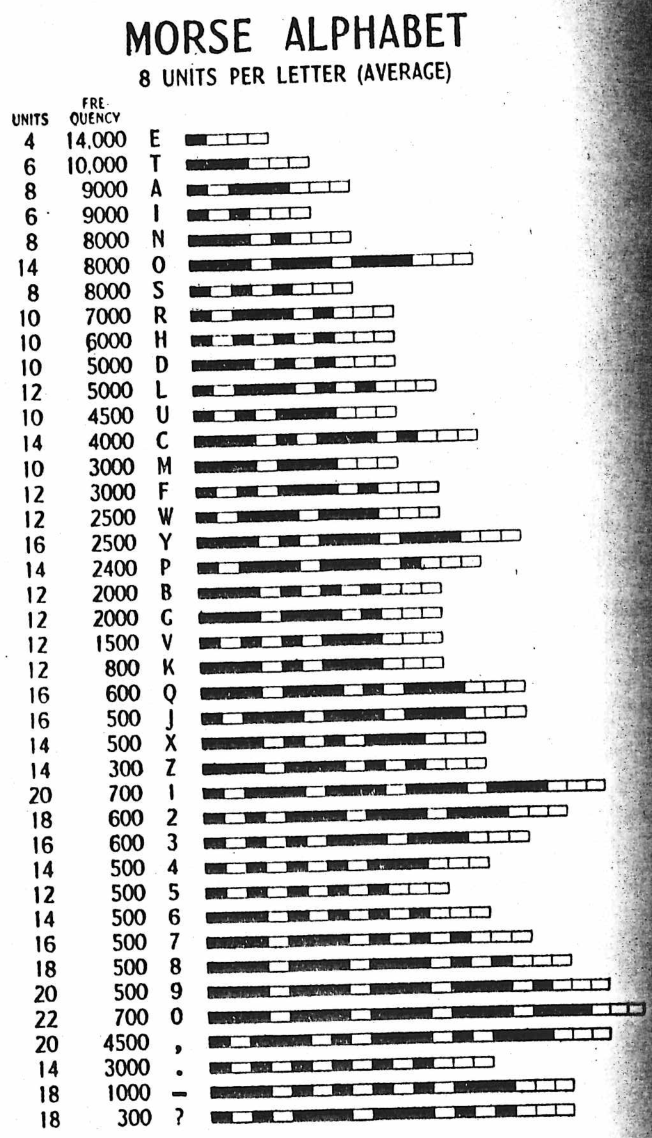


FIG. 4.

In the Rowland alphabet, as each current unit must be separated by at least one zero unit, a zero unit has to be added at the end of all the letters making it a 12-unit alphabet, and the exigencies of the Rowland



MORSE ALPHABET

8 UNITS PER LETTER (AVERAGE)

UNITS	FREQUENCY	
4	14,000	E
6	10,000	T
8	9000	A
6	9000	I
8	8000	N
14	8000	O
8	8000	S
10	7000	R
10	6000	H
10	5000	D
12	5000	L
10	4500	U
14	4000	C
10	3000	M
12	3000	F
12	2500	W
16	2500	Y
14	2400	P
12	2000	B
12	2000	G
12	1500	V
12	800	K
16	600	Q
16	500	J
14	500	X
14	300	Z
20	700	1
18	600	2
16	600	3
14	500	4
12	500	5
14	500	6
16	500	7
18	500	8
20	500	9
22	700	0
20	4500	,
14	3000	.
18	1000	–
18	300	?

FIG. 5.

stem require an extra unit, making 13 units per letter. In order to cure the advantage of "double-current" working, this alphabet, as ed in the Rowland system, is to some extent masked by being built out of an alternating current. (See foot of column in Fig. 4. This ows the 45th letter of the Rowland alphabet as actually transmitted.)

The beautiful automatic photo-printing telegraph system developed y the Siemens & Halske Company, in Berlin, is based on the same owland alphabet, but in this case it is not masked by the introduction alternating current. Each letter is represented by two short pulses, one positive and one negative, in eleven different positions.

If we remove the restriction that each current unit must be parated by at least one zero unit, we can at once make better phabets. The only condition to be observed is that not more than o different units must be employed, in order to leave the way open the use of the alternating current. We can, for instance, build up familiar Morse alphabet with positive and zero units, as on p. 562.

Or we may substitute negative units for zero units, and so conform type A (Fig. 2). The only point requiring mention is that the unison ice in the Morse alphabet consists of a negative or zero dash of 3 its, which is used for this purpose only. As the result of long perience with the Wheatstone, the British Post Office has found that average Morse letter is equal to four complete reversals—that is to y, 8 units. For manual signalling of all kinds, the arrangement upon ich the Morse alphabet is built is not only good, but it is practically only arrangement possible. There are only two different time ervals, namely, 1 unit and 3 units. For manual signalling, intervals and 4 units are not sufficiently distinct from 1 and 3. With chine telegraphy, on the other hand, time can be divided with at accuracy, and the use of more than two time intervals presents difficulty. Consequently with machine telegraphy a shorter alphabet Morse is possible.

Further, although the Morse alphabet is ideal for manual signalling, as a grave disadvantage for machine telegraphy. The letters are unequal length. Only those who have made a careful study of the nting telegraph problem from a mechanical point of view, can ise the extreme importance of this question in constructing a ting telegraph. Uniformity is the key to success in machinery. makes for simplicity. With all machinery, simplicity, other things g equal, is of prime importance, and owing to the delicacy and erent imperfection of telegraphic machinery, the need for simplicity his case is overwhelming. That simplicity can only be secured by gnalling alphabet in which all the letters are of equal length. It is same necessity that has compelled the use of letters all of the same h in typewriters. The Morse alphabet, however, has been in ssion of the field so long, and telegraph officials in English-speak- countries are so saturated with Morse traditions, that it would be ssible to introduce a new alphabet if the operators had to learn it. nately with machine telegraphy that is not the case. All the ator has to do is to learn typewriting. As a single illustration of mechanical advantages of an equal-letter alphabet, such as that

used in the Baudot and Murray systems, it may be mentioned
keyboard perforating instrument to produce the Morse tape for
Wheatstone transmitter, requires a group of nineteen punches and
corresponding parts, as against only five punches and their
ing parts in the Murray keyboard perforator. As an automatic
telegraph requires about four keyboard perforators at each end
circuit, if an equal letter keyboard perforator can be constructed
£20, and an unequal letter perforator costs £60, there is a difference
capital cost of about £300 per circuit in favour of the equal
alphabet. This is a large item if many circuits have to be equipped,
say nothing of the fact that cost of maintenance is roughly
to capital cost.

The alphabet used in the Buckingham printing telegraph has
peculiarity that it is both equal and unequal. It uses the Morse
and dash, but as each letter is represented by six impulses,
positive and three negative, it is not necessary to use the negative
solely as a unison mark as in Morse. Letters are distinguished
counting every sixth impulse, which is a negative dash, as in the
alphabet, but the negative dash is also used for building up the
permutations. The result is that the Buckingham is an
system at the receiving station; but at the sending station it is
in the complexities of an unequal-letter alphabet. The
alphabet is shown on p. 565.

The length of the letters in the Buckingham alphabet averages
10½ units, as may be proved by counting the number of units in
letter, and then counting the letters in several sentences and

The Best Machine Telegraph Alphabet.

Unquestionably the best alphabet for machine telegraphy is that
in the Baudot and Murray systems. It is the shortest of all
telegraph alphabets, in fact the shortest possible, and it is an
letter alphabet, consisting of five units per letter. The
are made up out of impulses of 1, 2, 3, 4, and 5 units' duration,
positive and negative (or positive and zero). Being an
alphabet, the signals can be divided off into letters by
There is, therefore, no need for a unison signal to separate the
as in Morse. Hence there is no space between the letters. The
is that impulses frequently extend from one letter into the next, and
average number of marking impulses per letter in the Murray
is only about 1¼, and a trifle more in the Baudot. In the
there are four and a half marking impulses per letter. The
alphabet, therefore, sends about three and a half times as many
per letter as the Baudot and Murray alphabet. The apparent
alphabet, as it appears in the perforated transmitting and
tapes, is shown in column B, Fig. 7, and the signals transmitted by
tape are shown in column C. Column A gives the frequency
occurrence of the letters of the alphabet.

The apparent Baudot alphabet as it is transmitted is
column D.

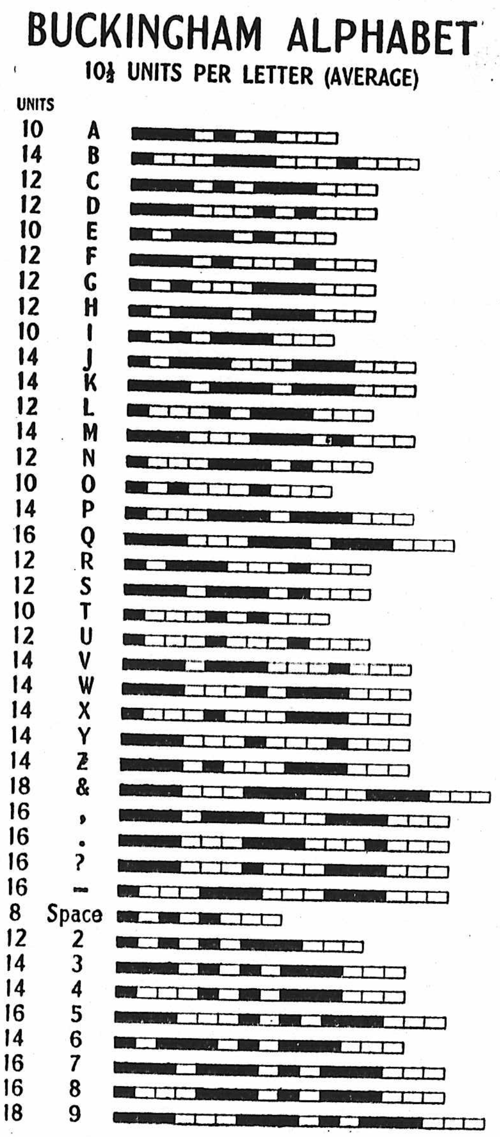


Fig. 6.

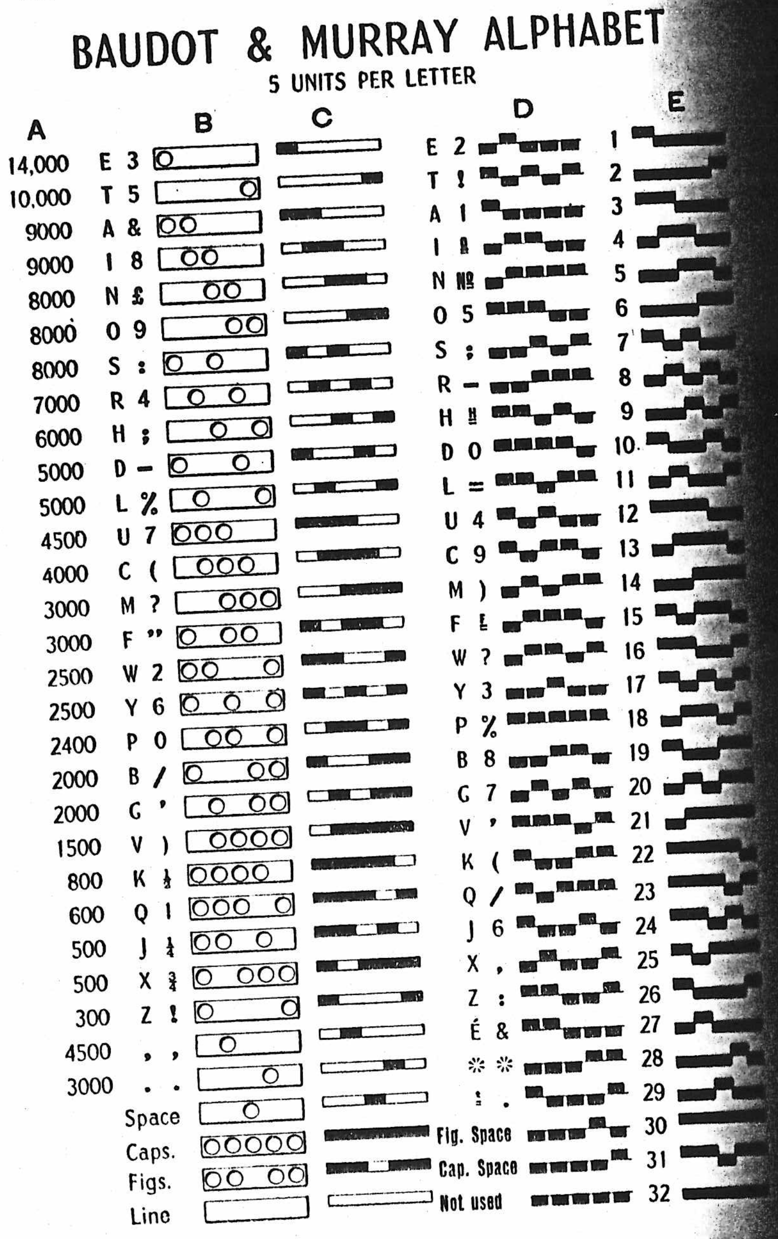


FIG. 7.

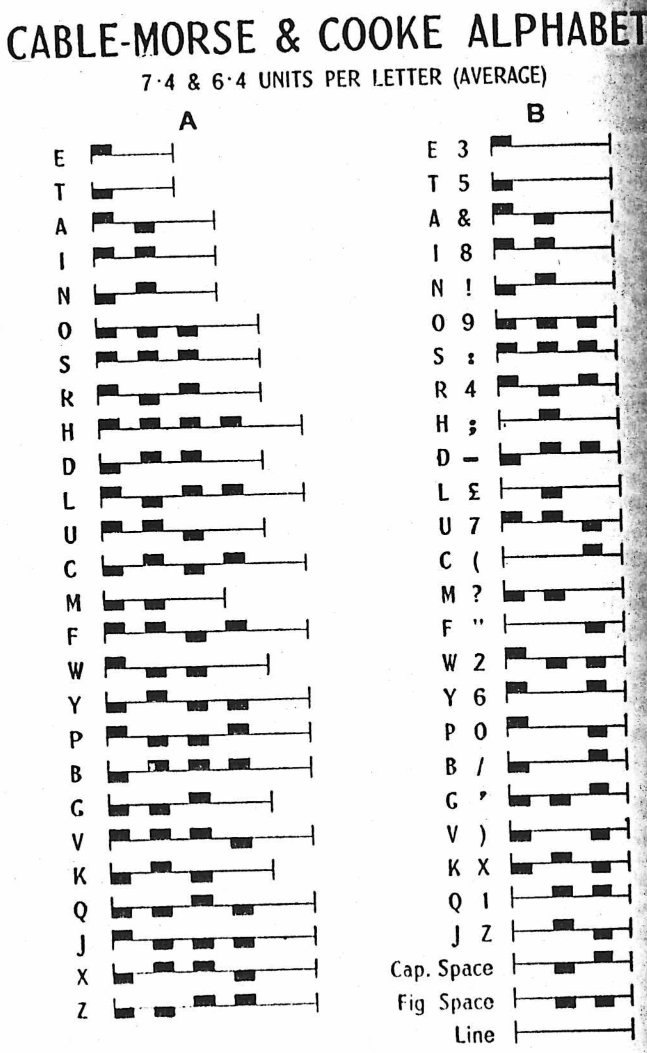
Actually the space between the unit signals in the Baudot is very small, and the groups of positive and the groups of negative signals run together into single signals, even in passing over a comparatively short line. The Murray alphabet is always worked with alternating current, so that the real Baudot and Murray alphabets as they actually go over a telegraph line are identical, and are shown in column E.

The only difference is in the allotment of the letters to the various permutations, the Murray arrangement being designed to punch as few holes as possible in the paper tape. Baudot, in a paper on his system in the *Bulletin de la Société Internationale des Électriciens*, vol. xi., credits the authorship of this alphabet to Wildman Whitehouse, in 1853, but the Whitehouse patent of 1853 gives only the alphabet shown in column B, Fig. 7, which was proposed by Morse and others, and is so obvious that no merit can be claimed for its use. To Émile Baudot belongs the credit of having been the first to use what I have described as the real Baudot alphabet. This is the shortest possible telegraph alphabet fulfilling the conditions already set forth, and it is the ideal alphabet for machine telegraphy. It was the natural outcome of the Baudot system. In the Murray system the instruments had to be specially designed with the express object of using this alphabet. It is the foundation of the great success achieved by the Baudot system during the past twenty years, and no system of machine telegraphy can hope for any wide and permanent success on land unless it uses this alphabet. Other alphabets, especially the Morse, will no doubt continue to be used with machine telegraphy for particular purposes, but the Baudot is the one alphabet that has any prospect of coming into general use for machine telegraphy. It bears the same relation to machine telegraphy that the Morse alphabet does to manual telegraphy. They are each without a rival in their respective spheres. Actually so far as the alphabet is concerned the Murray system has a slight advantage over the Baudot, because in the Murray system correcting impulses are generated from the signals themselves, whereas in the Baudot system two correcting units are required for every four letters, and on the average two units have to be allowed for retardation. Thus in practice there are six units per letter in the Baudot system and five in the Murray.

So far as ocean cabling is concerned, the number of possible alphabets is very limited. The Morse, as used for cable work, is shown in column A in Fig. 8 for the sake of comparison with the only equal-letter alphabet for ocean-cable work that is shorter than the Morse, namely, that shown in column B.

Cable Morse averages about 7·4 units per letter, and the equal-letter alphabet about 6·4, the advantage being about 10 per cent. in favour of the equal-letter alphabet. The use of this set of permutations (three different units in three different positions) as a telegraphic alphabet appears to have been first proposed by Cooke in 1836. So far it has not been put to any practical use, but there are interesting possibilities connected with it which will be referred to later on. It may be noted in passing that I have arranged the permutations so that fourteen of the most frequently used letters are the same as Morse.

Cooke's arrangement only provided for the twenty-six letters of the alphabet, and it does not seem to have been published.



CABLE-MORSE & COOKE ALPHABETS

7·4 & 6·4 UNITS PER LETTER (AVERAGE)

FIG. 8.

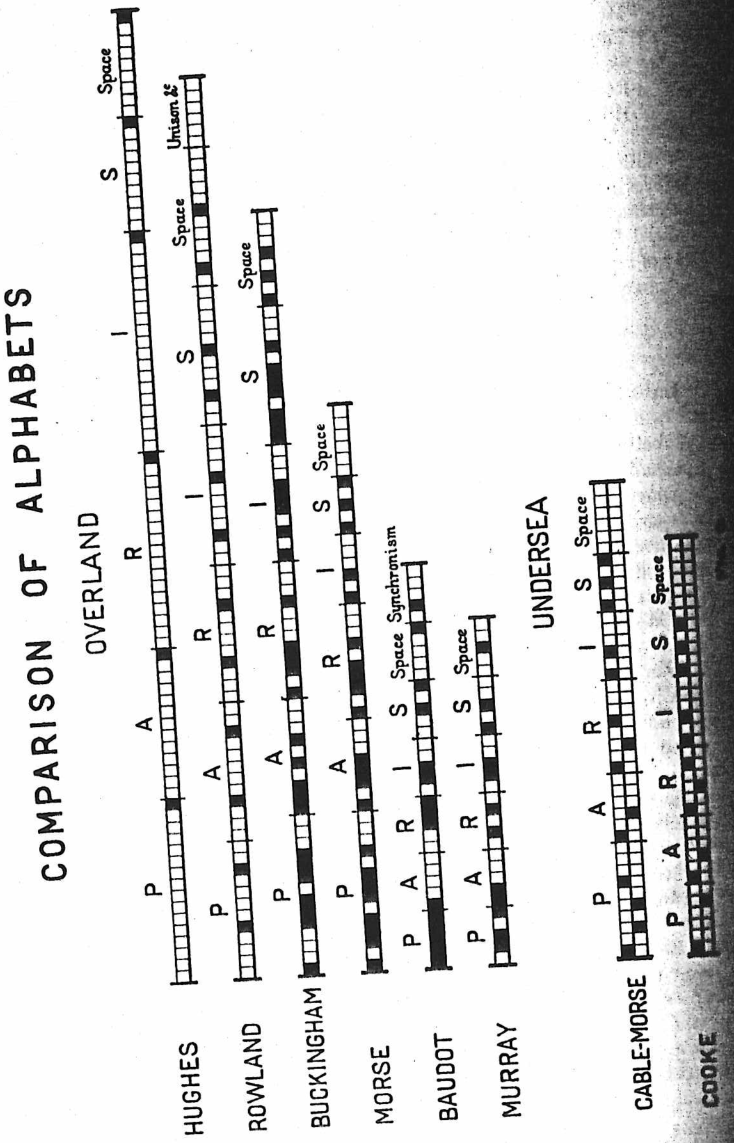
Summing up, the order of merit of the leading printing telegraph systems, from the point of view of economy of line-time by using the shortest alphabet or code of signals, may be set out as follows:—

	Five Letters.	Five Figures.
Murray	25 units	35 units
Baudot	30 "	30 "
Morse	40 "	74 "
Buckingham	50 "	74 "
Siemens & Halske ...	60 "	60 "
Rowland	65 "	65 "
Hughes...	75 "	75 "

With figures there is a slight difference, owing to the use of figure prefixes and suffixes in some cases and not in others. The foregoing estimate for figures is based on the figure group 13579. It will be noticed that with figures the Morse alphabet comes out badly. By way of a practical comparison the word PARIS is given in each of the alphabets, on p. 570.

SYNCHRONISM, ISOCHRONISM, AND UNISON.

Investigation having shown that the Baudot alphabet is the best, the next question is how to utilise it—and, in fact, any telegraph alphabet—as the basis of a printing telegraph system. As already explained, when there is only one wire or channel of communication, the conversion of space signals into time signals and back again may be regarded as the chief operation in printing telegraphy. If there were five wires, as at A in Fig. 10, the signals would remain space signals throughout. If, on the other hand, there is only one wire, as at B, Fig. 10, then there must be some means of putting the line successively in connection with the space signals 1, 2, 3, 4, 5, so as to collect them as time signals; and at the other end of the line there must be an arrangement to enable the wire to distribute its time signals successively to the space-signal positions 6, 7, 8, 9, 10. At each end of the line there must be an oscillation or rotation of some mechanism adapted for collecting and distributing the signals. This is one of the chief features of printing telegraphy, and therefore of all telegraphy through one channel. In the Baudot and Rowland systems we have complete rotation, a revolving contact arm sweeping the space signals successively into the telegraph line as time signals from a fixed contact-wheel and distributing them in the same way at the other end. In the automatic telegraphs the contact-wheel becomes infinitely large, that is to say, a rack, such as the Wheatstone transmitting tape. In this case, owing to the size of the wheel, it is impossible to have a revolving contact arm. Instead, the contact-arm is fixed and the wheel or tape-rack revolves. In B, Fig. 10, for instance, it makes no real difference whether the contact-arm revolves and the contacts 1, 2, 3, 4, 5 remain stationary, or *vice versâ*. The effect is the same in both cases. In nearly all printing telegraphs a revolving wheel distributor is used. In the case of the Hughes the distributor and the type-wheel are one and the same. In the stock-tickers it is a little ratchet-wheel on the same shaft as the type-wheel. In the Baudot, Rowland, and Buckingham the distributor is an entirely separate



mechanism from the type-wheel, and is connected with it in a very complicated manner. In the Murray system the distributor is a punch-arm and a moving paper-tape, that is to say, a portion of a rack. In this respect it closely resembles the Wheatstone recorder, but instead of inking the tape it punches holes in it. In the method of translating and printing after distribution of the signals, the Murray system differs from all previous printing telegraphs, and it belongs rather to the class of automatic type-setting machines, such as the monotype; and for the purpose of automatic type-setting in the ordinary acceptation of the word it was indeed originally designed.

It is owing to the necessity for converting space signals into time signals and back again that all telegraph systems using one wire or channel of communication involve "synchronism," "isochronism," and "unison." As already pointed out, if we had five wires instead of one, intelligence would be transmitted by space signals only. There would then be no need for a unison device, because each letter would stand by itself distinct, and there would be no synchronism, and only isochronism in respect of successive letters. With one wire the collector and distributor must both maintain the same speed—they must be isochronous—or the signals will get mixed up and lost. For instance, the sounder must work at exactly the same speed as the Morse key, though there may be considerable lag. There must also be a unison mark to distinguish the letters, the negative dash being used for this purpose in the Morse alphabet. The terms "unison," "synchronism," and "isochronism" are often very loosely used, but in telegraphy—

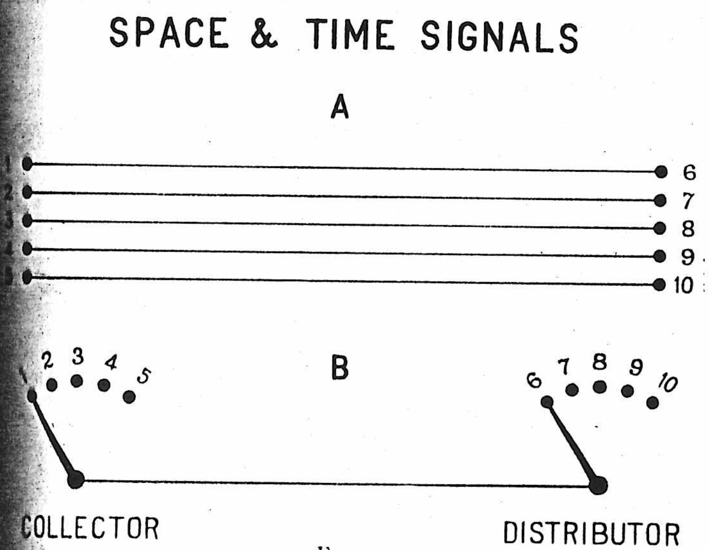


FIG. 10.

"Unison" is the method adopted for correctly dividing off or distinguishing the groups of letter signals.

"Isochronism" means identical speed of two bodies at a distance from one another.

"Synchronism" means identical speed and phase of two bodies at a distance from one another.

It is a physical impossibility to secure synchronism between a driving and a driven body, and in telegraphy all so-called synchronous systems are really only approximations to synchronism, and the more precise the synchronism required, the worse the system. Isochronism on the other hand is not only easy to secure, but may be made perfect.

In Fig. 11, if we take a shaft, D, with three wheels, A, B, C, keyed to it, and if B is the driving-wheel, then the speed of all three wheels must be identical or the shaft will break. That is to say, the isochronism is perfect, but the synchronism is not. The friction of the air on A will twist the shaft D and cause A to lag behind B. If D is a large steel shaft a few inches long, the lag will be infinitesimal, but if D is a telegraph wire 500 miles long, the lag becomes a serious factor. Although it is physically impossible to secure synchronism between a driving and a driven wheel, B and A, it is possible to secure synchronism between two driven wheels, A and C. The Baudot is usually worked as a synchronous system, and Fig. 11 is the method adopted in a Baudot repeating station. For instance, in the quadruple Baudot working between Paris and Berlin there is a repeating station at Coblenz, which controls the speed and phase of the instruments in Paris and Berlin. Coblenz is the driving-wheel B, and A and C are Paris and Berlin. This clever scheme secures perfect synchronism over 700 miles (1,100 kilometres) separating the two capitals, but unfortunately it is a thing that can only be done once, and in any case it does not really get rid of lag. The retardation of the signals has still to be allowed for. Hence there is a physical limit of say 500 miles (800 kilometres) to even approximate synchronism in telegraphy. Abandoning synchronism and relying simply on isochronism, the phase may differ to any extent, and the limitation of distance imposed by synchronism is at once removed. The Baudot has to abandon synchronism in order to perform its greatest feats. To get six transmissions over one wire between Paris and Marseilles, 550 miles (880 kilometres), two wires are used, one to send six messages simultaneously to Marseilles, and the other for six return messages to Paris. In this way lag or retardation is of no consequence as long as the signals remain clear, isochronism or identical speed being all that is required. Similarly, in working through 560 miles (900 kilometres) of single-wire ocean cable between Marseilles and Algiers, two transmissions of thirty words per minute each are secured in one direction through one cable, and another cable is used for the return messages. Between Marseilles and Algiers the difference of phase on the Baudot instruments amounts to about 90 degrees. The Murray system makes no attempt to secure synchronism. It is an isochronous system, and the duplex balance is used to secure working in both directions on one wire, the Murray system, like the Wheatstone, working very easily in this manner. Retardation under these circumstances ceases to be important, because the distributor need only keep step with the arriving signals, which might, if necessary, take five minutes on the journey. This arrangement has also the advantage that ordinary repeating stations can be used.

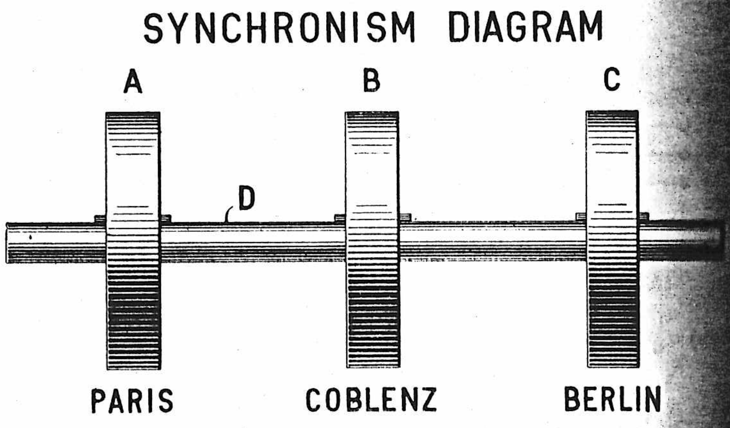


Fig. 11.

I would, therefore, prefer to describe as synchronous a telegraph system that endeavours to obtain sufficient identity of phase between the collector and distributor, to be able to work in both directions over one wire without resorting to the duplex balance. In this case the collector and distributor are identical in form, and can interchange their functions at will. A system relying on identical speed only, and the duplex balance for working both ways on one wire, is what, I think, would be described as an isochronous system.

What has been said about translation, collection, and distribution of signals may be summarised in the following chain of operations, forming the essential features of all printing telegraph systems:—

1. Message recorded in Roman or other type, or script handed in for transmission.
2. Translation into telegraphic space signals.
3. Collection of the telegraphic space signals in the form of time signals.
4. Transmission of the time signals over a single telegraph wire.
5. Distribution of the time signals in the form of space signals.
6. Translation of the telegraph space signals into Roman or other type characters.
7. Recording of the Roman or other type characters in the form of a message for delivery.

Although this chain of operations is complete in itself, something more is required for a high-speed printing telegraph. With a good telegraph alphabet, such as the Baudot, the capacity of a telegraph line for transmitting messages is so great that one operator cannot keep it fully occupied. If the line is to be completely utilised, it must, therefore, be given in turn to several operators. This involves some species of rotating mechanism. Hence the employment of several operators to send signals in rotation is only an extension of a process already in use. In Fig. 10, at B, it merely involves extending the number of space-

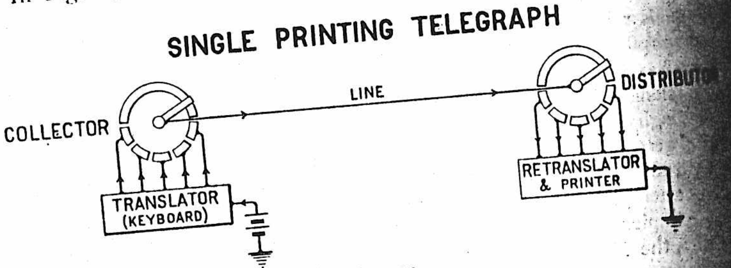


FIG. 12.

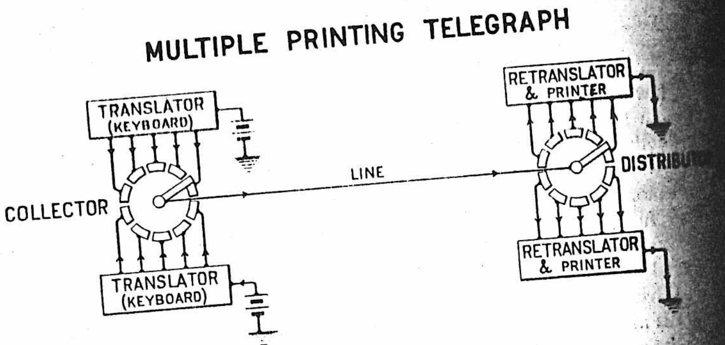


FIG. 13.

signal contacts at each end of the line. The employment of several operators is therefore easily and naturally provided for.

The operators may take turn about in transmitting (1) letters, or (2) messages. The first is the multiple method, of which the Baudot is the best example; and the second is the automatic method, of which the best-known form is the Wheatstone. The Murray system is simply a fully developed Wheatstone system using the Baudot alphabet. Each of these methods—the multiple and the automatic—has advantages and disadvantages which it is not possible to discuss here, beyond saying that the two methods appear to be in a sense complementary to one another, each being capable of doing work for which the other is not so well suited.

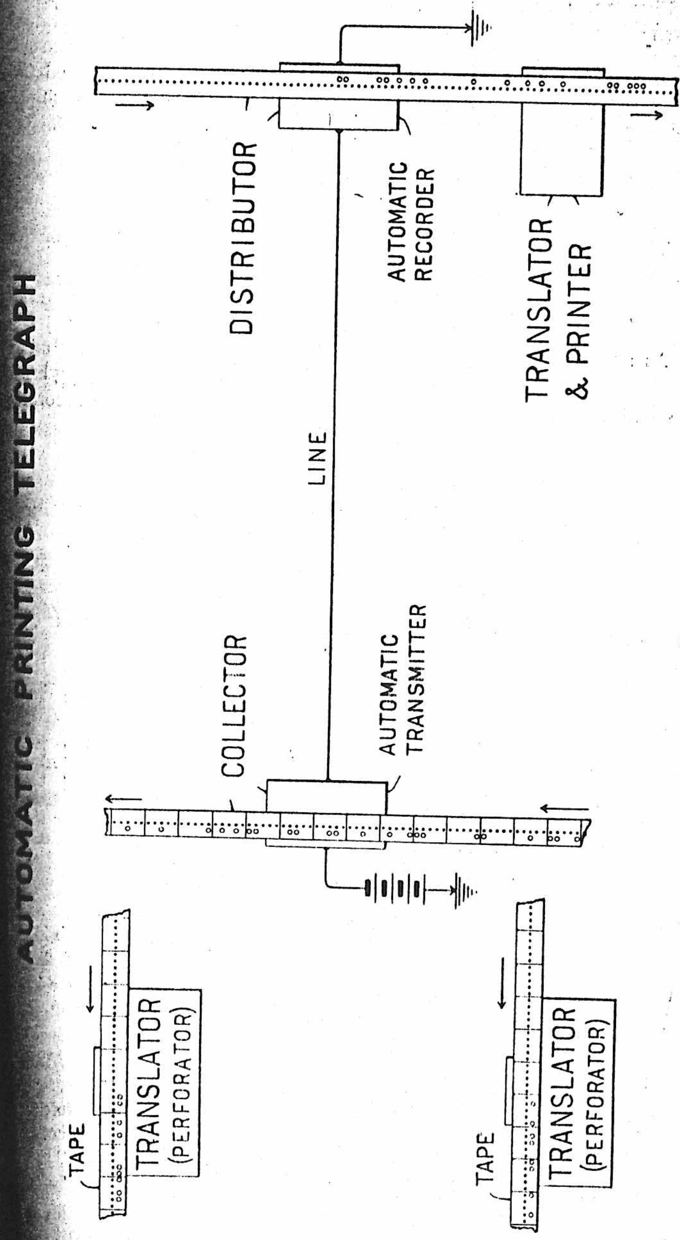


FIG. 14.

Figs. 12, 13, and 14 illustrate these and other points mentioned. Fig. 12 is a diagram of a single printing telegraph for one operator. Fig. 13 shows the multiple method by which several operators transmit single letters turn about. Fig. 14 shows the automatic method for transmitting messages turn about. It will be seen that the multiple and automatic methods differ only in degree and not in kind.

THE MURRAY AUTOMATIC SYSTEM.

The Murray automatic system may be taken as an example of the practical application of the principles that have been described.

THE MURRAY TAPE, AND THE CORRECTION OF ERRORS.

As already explained, the collector and distributor in the Murray system each consist of an oscillating arm or lever, and a moving band of telegraph tape about half an inch wide, the messages being recorded

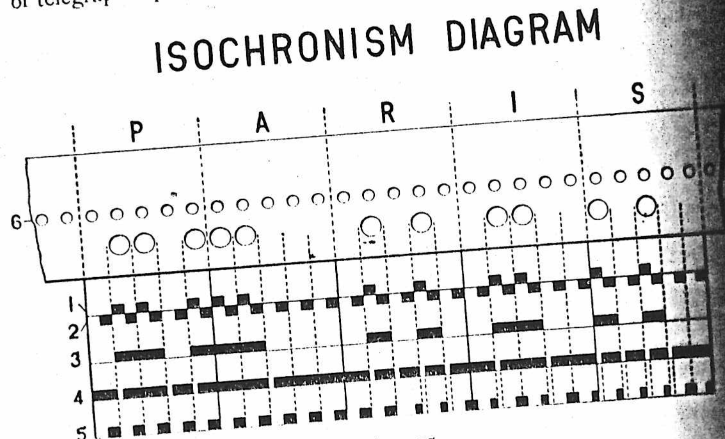


FIG. 15.

as perforations in the tape. The oscillation of the lever is a subsidiary feature arising out of the employment of tapping instead of sliding contacts. Relatively to the direction of motion of the tape, the lever or arm is stationary. Formerly the transmitting and receiving tapes were unlike, but they have now been made identical. Fig. 15 shows a piece of this tape perforated with holes representing the word "PARIS," while beneath it, on line 3, are shown the main-line time signals which this tape transmits, or which produce this tape at the receiving station. For the sake of clearness the main-line signals are shown made up of positive and zero units. The system can be worked in this way, but it is preferable, as already explained, to use positive and negative units (double-current), zero positions being filled with negative units. Each letter permutation occupies half an inch lengthwise of the

tape, each letter space being divided up into five equal units. Any one or more of these units may be perforated with a message hole. This gives 32 permutations. Following the example of the Hughes and Baudot, one of these groups is used as a figure shift and another as a letter-shift, and there are about 52 type characters. It is possible to use 84 characters, but the additional complexity is undesirable, and 52 characters have been found ample for all requirements. The central row of feed-holes in the tape 6, Fig. 15, is punched beforehand at an immense speed by pulling the tape through between a punch-wheel and a die-wheel. The same method is now used for perforating sheets of postage stamps, and it can be carried out on a manufacturing scale as soon as a demand arises.

While describing the tape, an important point in regard to automatic printing telegraphs may be explained. So far as commercial telegrams are concerned, a serious objection to direct-transmitting page-printing telegraphs is that errors show up badly in the printed message, and operators have to work slowly and carefully to avoid making mistakes. Telegraph operators are remarkably accurate, but in spite of the best care and skill, errors are frequent. Any one who is accustomed to using a typewriter knows how difficult it is to write a page of type-written matter without striking at least one or two wrong letters. In four cases out of five there is consciousness of the error as soon as it is made, and steps can be taken to correct it. In tape-printing telegraphs, like the Hughes and Baudot, the errors and the succeeding corrections can be cut out of the tape before it is pasted on to the telegraph blank, and there is then nothing to disfigure the telegram, and make the recipient uneasy about its accuracy. With a direct-transmitting page-printing telegraph this cannot be done. A wrong key depressed is an error printed at the other end of the line, and the correction following only magnifies the blot. All automatic systems of telegraphic transmission in which there is preparation of the message beforehand, possess the potentiality of correcting an error before transmission. In the Wheatstone automatic system, for instance, this process is known as a "rub-out." When an operator at a Wheatstone puncher makes a mistake he can pull the tape back and punch it full of holes, thereby obliterating the mistake. In this case the mistake is represented by a series of dots on the received tape, and the transcribing clerk passes over it. In automatic telegraph systems, in which a printing machine takes the place of the receiving operator, it is a comparatively simple matter to arrange that the printer shall imitate the action of the operator by remaining inactive when dots only are coming over the line. In this way no trace of the error appears in the printed message. This, for instance, is done in the Buckingham system. In the Buckingham system, however, as with Morse, the groups of letter signals on the transmitting tape are of varying length. It is consequently not possible to pull back the transmitting tape letter by letter in the keyboard perforator. It has to be adjusted by hand, or pulled back unit by unit, a process necessarily involving some loss of time, and many corrections in this way would materially reduce the output of the operator. In the Buckingham system also it is necessary to rub out everything as far as the end of the previous line. Hence, to correct a single letter a whole line may have to be rubbed out. With automatic systems like the Murray, using an alphabet in which the letter signals are all of the same length, the transmitting tape, while being prepared in the keyboard perforator, can be pulled back instantly letter by letter by depressing a lever. If an operator strikes a wrong key, all he has to do to rectify his error is to strike the back-spacing lever, the letter-shift key, and the desired letter—the work of a moment. A word of six letters can be blotted out in this way in a few seconds, and no trace of the correction, not even a blank space, will appear in the printed message at the other end of the line. This relieves the operator from the dread of striking a wrong key, the strain on his attention is less, and he can work faster without working harder. One or two automatic type-setting patents have included schemes for correcting errors in the perforated tape; but, as far as I am aware, the Buckingham was the first printing telegraph to adopt a plan for invisible correction, and the Murray system was the first, and, so far, is the only system having the power to correct instantly single letters or words.

THE FIRST TRANSLATION.

The messages for transmission are punched in the tape by keyboard perforators of a very simple character. These translate the Roman letter space signals into the space signals of the five-unit telegraph alphabet. Fig. 16 is a general view of this translating instrument, with the cover on and the lid opened like a piano, ready for operation. Fig. 17 shows the instrument with the cover removed. At the back there is a box holding a condenser to suppress the spark at the punching contact. On top of this box rests the ordinary Wheatstone tape-feed wheel. In front is the actual perforator, which includes a punch-block with five punches and an electromagnet, the armature of which punches on its front stroke and feeds the tape forward one letter space on its back stroke. This magnet does the whole of the work, and there are only two electrical contacts, one a punching contact and the other a letter-counting contact to indicate the length of the lines for the page-printing. There is also a typewriter keyboard with thirty-three keys, the touch and depression of which have been made very light and short to increase the speed of operation. A simple selecting or translating mechanism completes the machine. On the right may be seen the lever for pulling the tape back letter by letter when a correction is necessary. The correction is made by striking the letter-shift key (Caps.). This punches five holes in a letter space, and so blots out all other permutations which may have been previously punched. At the other end of the line this signal leaves the printer unaffected, its function being to shift the action of the printer from figures to letters. The signal may be repeated half a dozen times so as to blot out a whole word, and there will be no trace of the error in the printed message. the tape is divided off by printed cross-lines into letter spaces

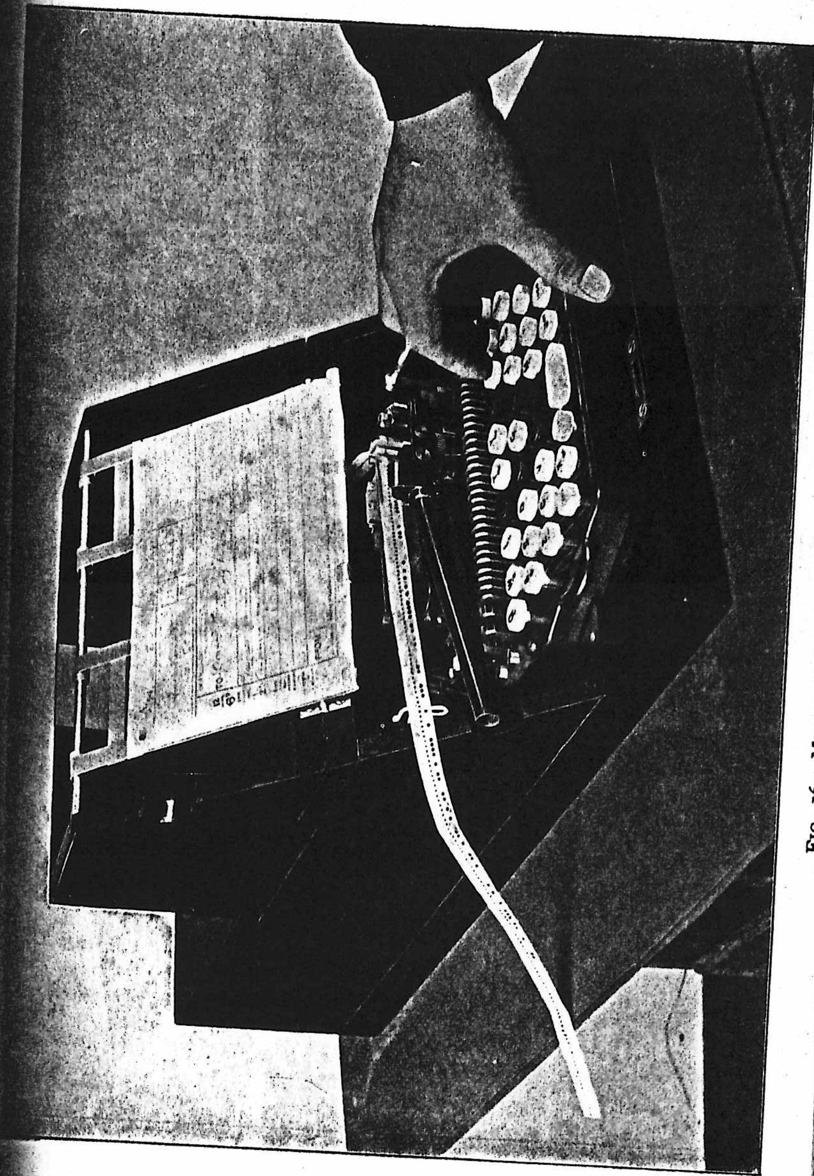


FIG. 16.—Murray Keyboard Perforator ready for use.

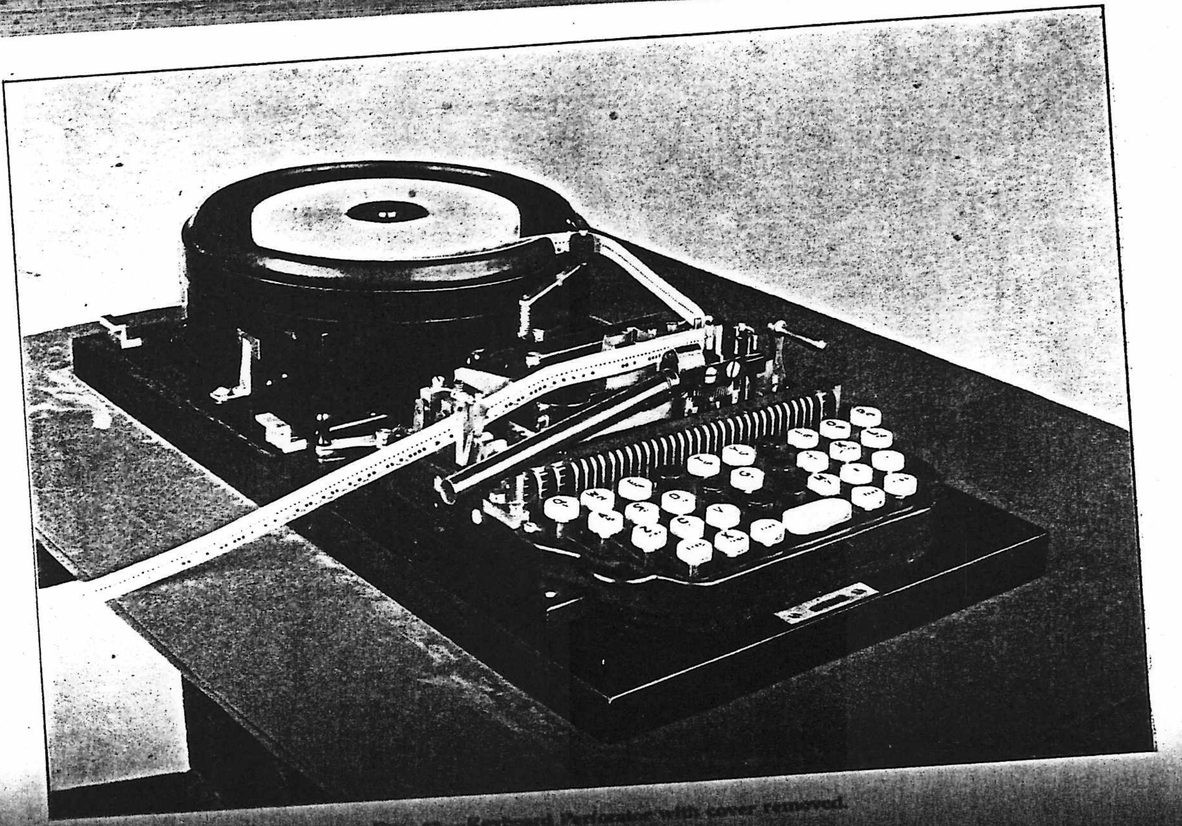


FIG. 17.—Keyboard Perforator with cover removed.

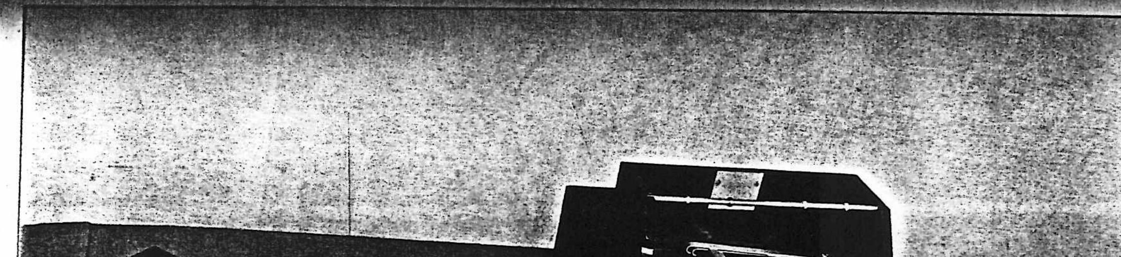


FIG. 18.—Keyboard Perforator lifted apart.

is practically as clear as print, and an operator can learn to read it in a week. It is not necessary to read the tape, but as it is easily learnt the perforator has been so designed that the perforated tape is visible up to the last letter punched just above the keyboard and below the message being perforated. In this way, what Wildman Whitehouse, in his remarkable patents of 1853 and 1854, describes as a "home record" is supplied for those telegraph administrations that require it.

The keyboard perforators can be constructed to work on any telegraphic voltage, or on a 110 or 220 volt electric-light circuit, and the current consumption is small—about one-third of an ampere during the momentary depression of each key.

SPEED OF OPERATION ON A KEYBOARD.

So many keyboard machines for producing perforated tape have been made during the past twenty or thirty years, that it is unnecessary to go into further details, beyond saying that the whole machine and any part of it have been made instantly removable and interchangeable. There are no screws, or terminals, or wires to be unfastened. If an instrument or any part of it is out of order, it is simply lifted away and another put in its place. Fig. 18 shows the parts separately. The key buttons are in rows of different colours and of slightly different heights to facilitate operation without taking the eyes off the copy—an essential condition for high speed on a typewriter keyboard. This mode of working is not so difficult as might be supposed, particularly when the operator is trained from the first to write in this way. A young telegraph operator in Berlin learned to write on one of the Murray keyboards in a fortnight, at the rate of 120 letters (20 words) per minute without looking at the keyboard, and this operator, after several months' practice, reached a speed of 436 letters 72 words) per minute in the same way. This is an exceptional case, and the operator was accustomed to piano playing, but it illustrates the possibilities of this method. The Hughes is habitually operated without taking the eyes off the copy, and in America the linotype operators have, during the past year or two, made a notable increase their speed by adopting the same plan, though the linotype keyboard is very large and contains ninety keys.

It may be mentioned in passing that there is much misconception about the speed of manual operation of keys and keyboards. In reality it is much below what is generally supposed. It is a subject great importance to telegraph administrations, and it has special bearings on the printing telegraph problem; but there is not space this paper to do more than point out that the average speed a typewriter keyboard is not more than about 120 letters (20 words) minute. Experiments with typewriter-keyboard instruments during past year or two in England, Germany, and the United States been very disappointing to telegraph engineers, owing to the exaggerated ideas that had previously prevailed about the advantages such an arrangement. The remedy, as already mentioned, is to train the operators to write without looking at the keyboard. It is possible that in this way the average speed may reach about 180 letters (30 words) per minute, or about double the average speed of a good Morse key operator. As the Murray system uses the five-unit alphabet, the five permutation keys of the Baudot system may be substituted for the present typewriter keyboard in the perforator. This would have the drawback that the operator would have to learn the permutations, the operator and not the machine then doing the translation; but it would have the advantage that the operator could keep his eyes on the telegram as easily as with the Morse key. In fact two sets of these permutation keys can be used, one set for the five fingers of each hand, to be worked alternately. But with properly trained operators the typewriter keyboard is undoubtedly the best.

COLLECTION AND TRANSMISSION.

The perforated tape, containing a batch of three or four messages, having been prepared, the next step is automatic transmission, that is to say collection of the space signals and transmission as time signals. There are two well-known methods of automatic transmission of telegraph signals from a paper tape. The first is the direct method, in which metallic brushes make electrical contact directly through the holes in the tape. The second is the indirect method employed in the Wheatstone automatic transmitter. This utilises the principle of the Jacquard loom, the signals being transmitted by the intervention of a number of small levers and rods controlled by the perforated tape. Experience has shown that the indirect method of transmission is more reliable than the direct method, and it has the additional practical advantage that by adjustment of the levers and contacts the relative duration of the positive and negative units can be regulated with great nicety. Another advantage of the indirect method of transmission is that the mechanism for perforating the transmitting tape is simpler and quicker than that required for making tape for direct transmission by contact brushes.

The object of the Murray single-line transmitter is to produce, from a series of adjoining but separate holes (1, Fig. 19) in a tape, not a series of short dots like 6, but a continuous telegraphic signal 3, such as would be produced by a contact brush passing over the slit of elongated perforation 2, equal in length to all the holes 1. The mechanism has also to break or reverse the current 4 when one or more unperforated units of tape 5 intervene, and to maintain this zero or reversed current in the line until one or more perforated units of tape occur. It is a process of integrating or producing a continuous signal from a series of discontinuous holes. The object is to reduce as far as possible the number of signals transmitted over the line by making the instrument transmit the real Baudot alphabet. If it were not for this arrangement the number of signals that would have to be transmitted to produce the Murray tape would be nearly double what it is now. It will be

seen presently that at the receiving station there are instruments which exactly reverse this process. They differentiate or split up the wholesale signals into their retail units, thereby producing at the receiving station a replica of the transmitting tape.

As there is only one row of message-holes in the tape, the Murray transmitter, in its improved form, is a considerable departure from the Wheatstone model. In the Wheatstone the signals depend on the relative positions of message-holes arranged in two rows. In the new Murray transmitter the signals depend on the relative positions of perforated and non-perforated units of tape. The mechanism is shown in Fig. 20 (collector). The tape and the transmitter together form the collector. There is the usual Wheatstone star-wheel 15 to feed the tape forward by means of the central row of holes, rack and pinion fashion;

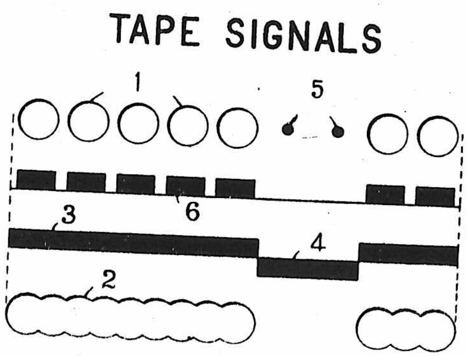
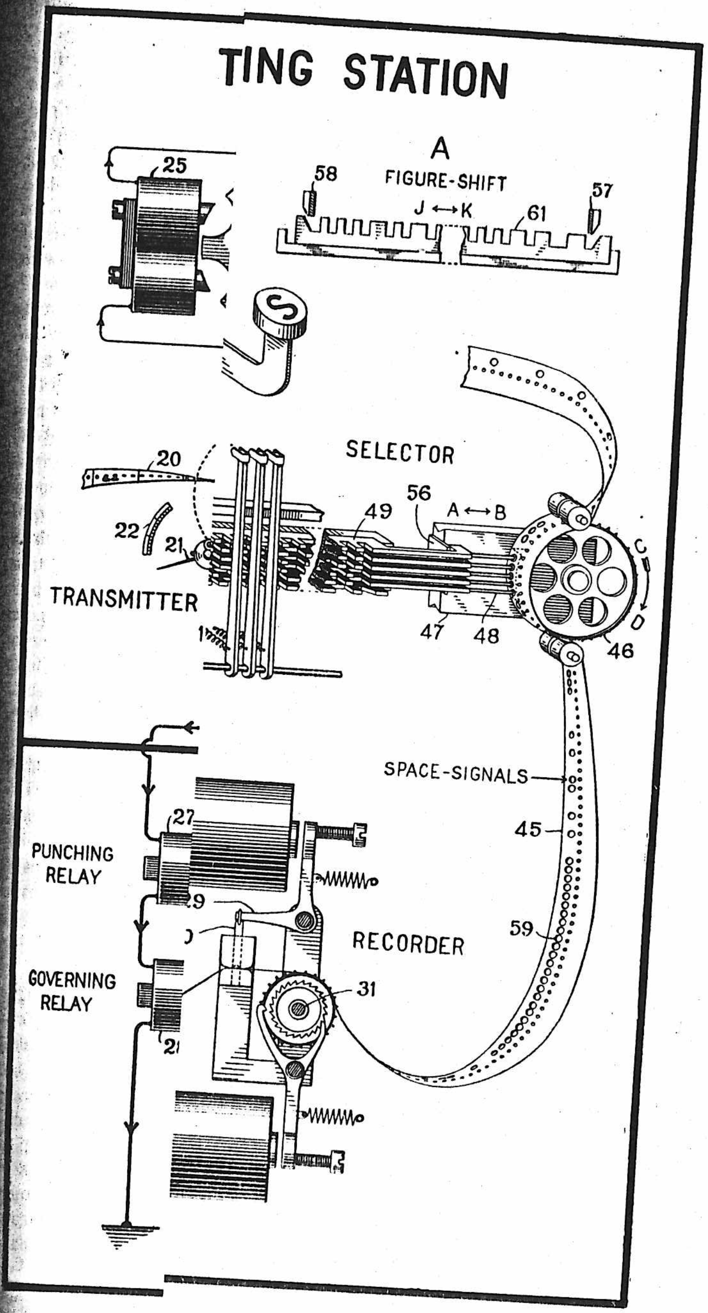


FIG. 19.

but in place of the two small upright rods used in the Wheatstone for entering the holes in the tape, there is a single rod 1. This rod is pivoted at one end of a horizontal thrust-lever 2. This thrust-lever is in its turn pivoted near its middle on a vertical lever 3, oscillating on the centre, 4. This vertical lever is kept oscillating steadily by a small eccentric wheel 5 and connecting rod 6, of the same kind as that employed in the Wheatstone transmitter. The thrust-lever 2 has a tooth 7 on its under side, which rests against a pin 8 in the vertical lever 3. The result of the oscillations of the vertical lever 3 is to cause the horizontal thrust-lever 2 to oscillate also. The free end 9 of this thrust-lever is placed close to the two free ends of two converging thrust-bars 10 and 11, which are pivoted one on each side of the pivot 12, of an ordinary Wheatstone contact lever 13. These converging thrust-bars are lightly pressed against a friction roller 14 by two small steel wire springs. The usual Wheatstone jockey roller 17 ensures the contact lever 13 making firm contact and remaining either on contact 18 or on contact 19.

When the machine is in operation, and tape perforated with a message is being fed through in the ordinary Wheatstone manner, the small steel rod 1 reciprocates regularly against the paper tape 20, as may be seen from the dotted arc 16 described from the centre 4. It makes one reciprocation for each unit of the tape, the eccentric wheel 5 making ten revolutions for one revolution of the star-wheel 15, the spindles of the two wheels being connected by ten to one gearing as shown by the large dotted circle. If there is a message hole in the tape, the tip of the rod enters the hole and the complete motion of the rod is unobstructed. This permits the thrust-lever 2 to move as if it were one piece with the vertical lever 3, and the oscillation causes its free end to strike the free end of the lower thrust-bar 11, connected with the contact lever below the pivot 12. This throws the contact lever over on to the marking contact 18. If at the next oscillation the small upright rod again enters a hole in the tape, the same action is repeated, but the contact lever being already against the marking contact, and held there by the jockey roller 17, no change is made in its position, and marking current continues to be sent out to line. No further repetition of message-holes in the paper tape makes any change in the position of the contact lever; but if a non-perforated unit of tape intervenes, then the small rod 1 is obstructed by the tape, and the oscillation of the vertical lever 3 causes the rod 1 to depress its end of the thrust-lever 2, thereby raising the other end 9 of the thrust-lever, which then, in the course of the oscillation, strikes the upper thrust-bar 10. This throws the contact lever over on to the spacing contact 19, thereby breaking the marking current and throwing spacing current into the line. If in the next oscillation another non-perforated unit of tape intervenes, the same action is repeated, but as the contact lever is already resting on the spacing contact, no change in its position takes place, and spacing current continues to be sent out until a perforation occurs in the tape. This, by the action already explained, throws the contact lever over again on to the marking contact. It is always the first of a series of perforated units or the first of a series of non-perforated units of tape that operates to throw the contact lever over from one contact to the other. By this means the space signals punched in the tape are converted into time signals of the real Baudot alphabet.

There are a number of details connected with the transmitter, but the only one worth mentioning is the method of getting rid of bias—that is to say, the method of ensuring that the positive and negative half-waves or units shall be both of the same length. In the Wheatstone transmitter, bias is shown by the galvanometer needle inclining to the right or left according as the positive or the negative half-waves are longer, when reversals are sent. The contacts are then adjusted till the bias ceases to show on the galvanometer. The best that can be said for this arrangement is that it is rough and ready. In the Murray transmitter a more precise and scientific method is used. The eccentric wheel 5, Fig. 20, makes one complete revolution for each half-wave, positive or negative. A small steel pointer 21 is inserted in the eccentric wheel, and on the frame of the machine there is a short scale 22. If the transmitter is driven very slowly by hand the galvanometer needle will be observed to come to zero at the moment when the



positive or the negative contact is broken. If the pointer points to the same division on the scale for a positive break as for a negative break, then there is no bias, and the positive half-wave is the same length as the negative half-wave. If, on the other hand, the pointer is alternately in advance and in retard for each half-wave or unit, then bias exists, and the contacts have to be adjusted till it disappears. As each half-wave or unit is equal in length to the circumference of the circle described by the tip of the pointer 21 it will be seen that bias is not only shown on a magnified scale, but is exactly measured. Absence of bias —that is to say, correct timing of the signals, is important in all systems of machine telegraphy, including even such simple apparatus as the Wheatstone automatic, and the indicator just described leaves nothing to be desired as far as the Murray system is concerned.

Fig. 21 is a general view of the transmitter. At the back may be seen the rectangular frame of a La Cour phonic wheel motor that drives the transmitter. This motor is more clearly shown in the general diagram of the system, Fig. 20. A vibrating reed 23 sends electrical impulses alternately to the two motor magnets 24 and 25, and these keep the notched armature 26 in steady rotation. This armature so drives the star-wheel 15 and eccentric wheel 5. The arrangement is in reality an electrical pendulum with the action reversed, the pendulum driving the escapement wheel, the two magnets being the two pallets of the escapement which pull the escapement wheel 26 round step by step, though the inertia of the wheel is sufficient to ensure uniform motion. The vibrating reed being isochronous in the acoustical sense, the speed of the motor is the same for all amplitudes of vibration. That is to say, variation of current strength has no effect on the speed of the motor. The speed is remarkably uniform, and the motor is ideal for the purpose and gives no trouble.

This single-line transmitter has several advantages over the Wheatstone instrument, the chief one being that there is a direct thrust against the contact lever from the driving mechanism, independent of the strength of the paper tape. Hence this thrust can be made strong in order to give very firm contacts.

The Distributing Mechanism.

The distributor at the receiving station consists of two relays, a vibrating reed, and a recorder. In practice the main-line signals pass through an ordinary polarised relay to earth, this relay operating two local relays; but for the sake of clearness the main-line signals are shown passing direct through the two local relays 27 and 28, Fig. 20, to earth. It is by means of these two relays that the rest of the distributing mechanism is controlled. The recorder, which punches the message-holes in the receiving tape, is also shown in Fig. 20. This recorder consists of a punching magnet and a spacing magnet. The punching magnet operates a punching lever 29 and a punch 30. This punch corresponds with the small rod 1 in the transmitter. The punch reproduces the motions of the rod, and thereby reproduces the perforations in the tape. On short circuit the punch and the rod may be seen to be working precisely in step with each other. The spacing magnet feeds the tape forward unit by unit by means of the escapement and star-wheel on the motor-driven spindle 31. In order to secure the alternating action of these two magnets, the contacts which close their respective circuits are arranged one on each side, 32 and 33, of a vibrating reed 34, driven by a magnet 35. As the reed vibrates, short impulses are sent alternately to the punching and the spacing magnet. When there are no signals passing in the main line, a special device (not shown) cuts out the spacing magnet by opening the switch 60, and so stops the tape; but as long as a message is passing the vibratory action of the spacing magnet is continuous, and the tape is fed forward at a fixed speed. The punching magnet works alternately with the spacing magnet, but only when there is marking current in the main line, the punching relay 27 controlling the circuit of the punching magnet. The oscillations of the tongue of relay 27 and of the vibrating reed must therefore be not only isochronous, but also synchronous. Between sending station and receiving station isochronism only is needed, but between the receiving instruments on the same table synchronism is essential. This is the case not only with printing telegraphs, but with all machines. The parts must move synchronously or the machine will not work. Fortunately, practical synchronism, when it is a question of a few inches and not of miles, is very easy of attainment. In the Murray system it is achieved in the following manner, which also of course secures the needful isochronism between the two stations.

The Method of Securing Isochronism.

The reed 34, kept vibrating by the magnet 35, beats against buffer springs 36 and 37. These limit the amplitude of vibration, and, as the energy imparted to the reed must find some outlet, the frequency is increased. Without buffer springs the amplitude of vibration varies in proportion to the strength of the current through the reed magnet, but the frequency is wonderfully uniform. The reed is then isochronous in the acoustical sense. With a fixed amplitude determined by the buffer springs the frequency varies with the strength of the current. The reed is no longer isochronous. Its speed becomes very sensitive to variations of current, and can therefore be controlled by controlling the current to the reed magnet. If the circuit of the reed magnet 35 is traced from the battery 38, it will be found that it has two break-points—one at the contact of the tongue 39 of the governing relay 28, and the other at the reed contact 40. The punching and governing relays are identical in all respects, and they are driven by the same power, so that their synchronism is perfect. (They are driven wheels only a few inches apart.) The tongue 39, therefore, moves in exactly the same time as tongue 41. Hence as long as tongue 39 oscillates synchronously with the reed, tongue 41 will do the same. In fact, the two relays might be replaced by one relay with two tongues. The back and front stops, 42 and 43, of the governing relay are electrically united, so that at the beginning and end of a main-line signal when the tongue of the governing relay crosses from one contact to the other, there is a momentary break in the reed magnet circuit during the time of the transit of the tongue. This transit time can be varied to a considerable extent by adjusting the position of the contact stops. Opening the contacts increases the governing effect and closing them diminishes it. The reed magnet 35 breaks its own circuit at 40 in the usual vibratory way. If the reed 34 is oscillating in synchronism with the relay tongue 39, then full vibratory impulses will flow through magnet 35, as the two contacts at 39 and 40 will be opened and closed simultaneously. But if the reed tends to go faster than the arriving signals, then the two contacts 39 and 40 no longer open and close together, but more or less alternately, and the current impulses in the magnet 35 are more or less clipped. This reduction in the supply of energy to the reed at once reduces its speed till the contacts are again simultaneous. In practice the receiving vibrator is set to run about 2 or 3 per cent. faster than the arriving signals, and the governing action of the two interfering break-points in the same circuit results in the establishment of a steady dynamic balance between the accelerating tendency of the reed and the retarding tendency of the arriving signals. The effect is exactly the same as that produced by two taps in a water-pipe. If both are opened and closed together the water flows through in gushes; but if they are opened and closed alternately no water gets through, and more or less water gets through accordingly as the taps are opened and closed more or less alternately. By this means the relay tongue 41 not only vibrates at the same speed as the reed 34, but preserves the same phase. That is to say, tongue 41 touches contact 44 at the same time as the reed touches contact 33, even when the reed is making seventy-five vibrations per second (150 words per minute). But the tongue 41 does not move for every vibration of the reed. For instance, if there is a 4-unit marking signal coming over the main line, then the tongue 41 closes on its punching contact 44 for an interval of 4 units' duration, and the reed then makes four vibrations, touching the contact 33 four times, and in this way punching four successive holes in the tape by the alternate actions of the punching and spacing magnets. The transit intervals of the tongue of the governing relay 28 might be said to be like the teeth of an old saw. Some are there and some are not, but such as remain are all at unitary distances from one another (see line 4, Fig. 15). So also with the signals, and there are always enough signals to govern. Actually one correction per letter is sufficient, but on the average there are not less than two and a half, because each main-line signal gives two corrections, one at the beginning and the other at the end of the signal. As a matter of fact the governing action may be stopped during the arrival of as many as six or eight letters without upsetting the isochronism, and if a line disturbance or other cause throws the reed out of step it comes in again within five letter spaces—that is to say in half a second at a hundred words a minute. The reed is only in step as long as signals are coming over the line, and it goes out of step at the end of a batch of messages, but five space signals at the beginning of a new batch of messages bring it in again ready to record the messages. By this arrangement the necessity for sending correcting impulses over the main line to secure isochronism is avoided, the correcting impulses being generated locally from the arriving letter signals themselves. In this respect the Murray system has followed the excellent example set by the Hughes.

The isochronism diagram, Fig. 15, illustrates the co-operation of the current impulses. It shows a section of receiving tape punched with the word "PARIS." Beneath are the current impulses, indicated by black bars. Line 1 shows the impulses given to the punching magnet by the successive contacts of the reed 34 with the contact 33. Line 2 shows the uninterrupted succession of impulses to the spacing magnet from the reed contact 32. Line 3 shows the main-line signals. This illustrates the great saving of line signals effected by the special arrangements of the collecting and distributing mechanisms. Without these special arrangements it would be necessary to transmit over the main-line the signals shown in lines 1 and 2, that is to say, about five times as many signals as are now required. Line 4 shows the gaps in the circuit of the reed magnet 35 made by the crossing from contact to contact of the tongue 39 of the governing relay. Line 5 shows the impulses generated by the reed contact 40. As long as these impulses do not get into step with the gaps in line 4 they are not interfered with; but directly they do they get clipped, as shown for the sake of illustration in the second half of line 4. The speed at the two stations can, of course, be varied by altering the position and size of the weights on the vibrating reeds at the two stations.

A speed of no less than 900 letters (150 words) per minute in one direction has been reached with this recording mechanism, at which speed the punching magnet has to punch seventy-five holes per second, and the punching and spacing of the receiving tape have been perfectly performed at 960 letters (160 words) per minute, or eighty holes per second. Even this is not the limit, and it is possible that the speed might be forced up to even 1,200 letters (200 words) per minute. As half the time is required for spacing, the punching of eighty holes per second means that the punching magnet operates in $\frac{1}{160}$th of a second. As it takes a pressure of about 2 lbs. to force the punch through the paper, the punching magnet can not only operate with considerable speed, but also with considerable power. For ordinary commercial telegraphy there is no necessity for such high speed, and it is probable that, if the Murray system comes into general use in preference to other systems, the speeds required will be from about 240 letters (40 words) up to about 720 letters (120 words) per minute.

The transmitted signals having been correctly distributed along the receiving tape 45, Fig. 20, by the recording mechanism just described, the tape may then be used in its turn for again transmitting the signals over other circuits, or it may be run through the printer to translate the signals into printed letters. As the signals when retransmitted are sent on in as perfect shape as from the original transmitting station, it is possible to transmit messages in this way at a high speed to any distance overland—from London to Calcutta, if need be. Owing to

the power to retransmit from the received tape, it is also possible to transmit messages from any number of stations A, B, C, to station D, and to sort out the messages there and retransmit automatically in accordance with the addresses to any stations E, F, G, any one or more of which may again retransmit messages requiring to be sent on still further.

THE SECOND TRANSLATION AND PRINTING.

If the tape is not required for retransmission, then the tape signals have to be translated into Roman letters and printed. The essential features of the Murray printer are shown in the general diagram, Fig. 20. The tape is fed along letter by letter (five units at a time) by a star-wheel 46, carried on a shuttle 47, which is kept reciprocating in the directions shown by the double arrow A–B, by means of a cam, each reciprocation rotating the star-wheel one letter space as shown by the arrow C–D. The shuttle carries a die-plate coinciding with the circumference of the star-wheel, and having five holes corresponding with the message-holes in the tape. Five rods 48, fixed in the ends of five slotted combs 49, are free to enter the five holes in the die-plate if they are not obstructed by the paper tape which passes between the rods and the die-plate. On its inward stroke the shuttle with its die-plate presses the tape, with a letter group of perforations, against the ends of the five rods 48. Rods that are opposite holes in the tape pass through into the die-plate, and the positions of the corresponding combs are not altered. But in the case of non-perforated units of tape the corresponding combs are thrust back about $\frac{1}{16}$th of an inch. By this means one particular group of slots in the combs, and only one out of fifty-six, is brought into alignment so that a latch or cross-bar 50 can drop into it. Although only four latches are shown, there are fifty-six of these small levers, one for each of the fifty-six permutations or groups of slots. The latches or cross-bars are supported by a universal bar 51 just clear of the teeth of the combs. At the right moment this bar drops in the direction of the double arrow F–E and leaves all the cross-bars resting on the combs; but only one out of the fifty-six is selected by the particular aligned group of slots corresponding to any particular group of holes in the tape.

From the point of view of the theory of machines, the combs form a complicated system of fifty-six inverse permutation locks. The fifty-six cross-bars are the bolts or latches, and the universal bar 51 is a universal key. The locks are continually being closed in different ways by the tape, and the universal key 51 is continually opening the locks. The tape, however, is only an intermediary. The locks are really closed selectively by the keys of the perforators at the transmitting station, the keys of the perforators being real keys in the ordinary sense of the word, and not nominal keys like those of a typewriter. The letter signals sent over the line are an exact copy of the wards of the keys of the keyboard perforators. This intricate system of keys and locks is inevitable in all cases where complex control is needed. Amongst other instances it is used in systems of railroad interlocking gear. In outward appearance there is no resemblance between the Baudot and the Murray telegraph systems, but the principle of the permutation locks is the same in both cases. Fig. 22 A shows the system of permutation locks in the case of the Baudot, and Fig. 22 B that employed in the Murray system. As the Baudot prints from a type-wheel, the locks are arranged round a wheel, and as the Murray prints by means of the straight row of keys of a typewriter, the locks are arranged as a rack. Fig. 23 shows an average permutation letter signal of the Baudot and Murray systems, the Morse, the Rowland, and the Hughes drawn on the same scale, and, for the sake of illustration, in the form of ordinary keys.

Let us assume that latch or cross-bar 50 in Fig. 20 has been selected. This cross-bar, under the action of its spring 52, throws a hook 53, attached to a typewriter key 54, under a striker-bar 55, which is continually oscillating in the directions shown by the double arrow G-H, and the typewriter key is in this way sharply depressed so as to print. The object of this arrangement is to secure speed and smoothness of action. The moment the hook 53 is engaged by the striker-bar 55, the system of locks can be opened by the universal bar 51 and closed again with a fresh letter permutation simultaneously with the printing of the last letter. This arrangement practically doubles the speed of the printer. The shuttle on its outward stroke restores the combs to their original positions by means of the plate 56, which engages with inward projecting teeth on the overhanging ends of the combs. The cycle of operations, including the rotation at the right moment of the star-wheel 46 through one letter space, the reciprocation of the shuttle 47, the reciprocation of the universal key-bar 51, the oscillation of the striker-bar 55, and the return of the combs to zero position ready for the next letter, is performed by the usual battery of cams to be found in all automatic machines in which the cycle of motions is short and repeated millions of times. When the cycle of automatic motions includes hundreds of different successive motions and is only repeated thousands of times, we find, in place of cams, a chain of perforated cards, or similar devices, as in the Jacquard loom. When the cycle of

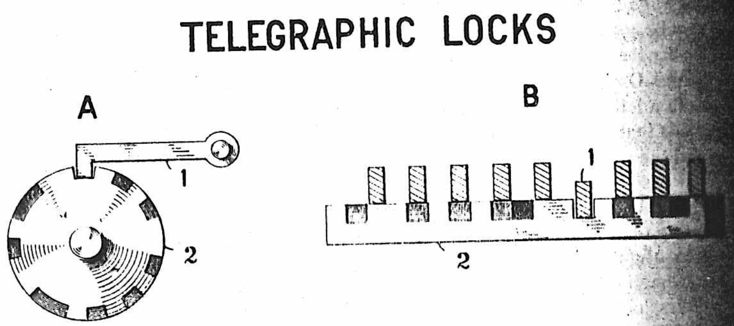


FIG. 22.

motions to be performed is infinite and is performed only once, we get the perforated tape of the automatic telegraph. In this case the tape only repeats when it has to influence the motions of a large number of individuals, that is to say, in the case of press dispatches. In the case of a telegram to a private individual the tape is used once only. In other words, the motions with which telegraphy has to deal are enormously more complicated than those in the most complicated known system of weaving. That is probably one explanation of the slow progress that has hitherto been made by machine telegraphy.

Although in the Murray printer there are only five combs with rods 48, there is a sixth comb 61, which in one position causes figures to

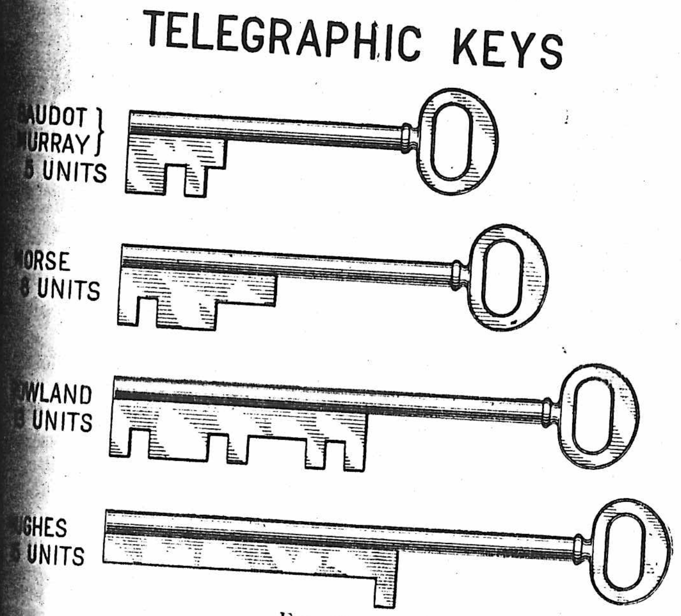


FIG. 23.

selected and in the other position letters. It is operated by two al cross-bars, one at each end. This arrangement is shown more ly at A, Fig. 20. At each end of this comb will be noticed a ped slot, and the two cross-bars shown in section at 57 and 58 wedge-shaped pieces for striking the edge of these V-shaped. When a figure-shift signal is transmitted, it selects the figure bar 58. This drops into its group of slots, strikes against the g edge of the figure-comb slot, and moves the comb $\frac{1}{16}$th of an the left in the direction J, thereby opening the figure-locks and the letter-locks. A letter-shift signal succeeding a group of operates 57, which restores the figure-comb to its original , in which the machine prints letters. If the letter-shift signal, ooooo (Caps), is repeated, no further action takes place, and the prin remains idle till a letter signal comes along. Thus, in the tape at Fig. 20, there is a correction consisting of five letter-shift sig which have been used to "rub out" a wrong word of five letters. the reason just given the printer remains idle during these five le spaces, and there is no trace of the error in the printed message.

An interesting point is the method of securing unison. In Murray system the question of unison is removed from the line the tape. As with the Wheatstone recorder tape, it is a quest of correctly dividing up the signals on the tape. With the five-u alphabet each letter occupies five units, or half an inch on the Hence to divide up the signals properly we have to start at the ri unit and then measure 5 units at a time. The star-wheel

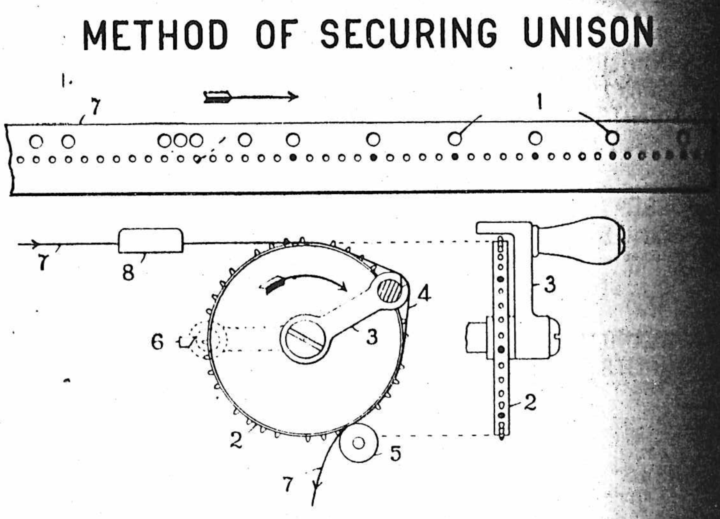


FIG. 24

Fig. 20, does the measuring, and all that is necessary is to plac tape properly on the star-wheel. To enable this to be done facility, each batch of messages begins with four or five space as shown in Fig. 24 at 1. The space signal is a perforation third-unit position. In the star-wheel 2 it will be noticed that fifth tooth is omitted and the vacant tooth positions blackened. tape 7 is inserted in the machine so that the space holes 1 come op the missing teeth of the star-wheel which show up black through fifth central hole in the tape, as shown for the sake of illustration blackened centre holes in the tape opposite the space signals 1. tape is then in unison. In the event of it not being in unison, be put in step by rotating the small unison arm 3. This bags tape as shown at 4, and advances the tape on the star-wheel

tent of one unit. A maximum of four and an average of two revolu- ons of the unison arm 3 brings the tape into step. The roller 5 is ring-pressed, so that it gives way and permits arm 3 to pass. The ison arm when not in use is held locked in the dotted position by e spring-tooth 6. 8 is a guide for the tape. The missing teeth in the r-wheel and the space signals show at a glance at the beginning of message whether the tape is in step. If a line interruption causes unison to fail in the middle of a message, two or three revolutions the unison arm by the attendant set all right again. This does not en happen, however, as a line interruption must be complete for least seven letters before the unison can be affected. Momentary rruptions do not disturb it. Apart from occasional line interrup- s the receiving mechanism perforates the tape with surprising uracy. On short circuit it will run for hours without making a gle false perforation.

In regard to the printing of the messages on telegraph forms, there four motions of the sheets of paper to be provided for, two horizon- and two vertical, as follows:—

Horizontal	Letter feed. Line feed.
Vertical	Column feed. Page feed.

The letter feed is already performed automatically by the type- ter. To provide for an automatic line feed, there is a small letter- ting device on the keyboard perforators. This indicates the end typewriter line of about seventy letters. A key is then depressed ch punches a line signal in the tape. This is transmitted to the iving station, where it operates a special key of the typewriter, h throws in a clutch, causing automatic mechanism to pull the writer carriage back to the beginning of the line. The same n provides the column feed up to a new line by a simple arrange- t used in most modern typewriters. The page feed is more com- ted and has not yet been made completely automatic in any ing telegraph, although there are several automatic page feeders g good service with printing presses. In fact, many of the rn illustrated magazines are printed automatically from a pile of heets by this means. At present, in the Murray system, the page is managed as follows: A stop signal is transmitted on the tape e end of each message, and this not only runs the typewriter ge back to the beginning of a new line, but also stops the printer. ttendant then pulls out the finished message by hand, and by a e device it automatically tears off at the right point, leaving the telegraph blank pulled in to the right starting point. The atten- then presses a button, which starts the printer on the next ge. The process is quite rapid. Later on it may prove worth to make the page feed completely automatic. The printer will feed itself from a pile of cut telegraph blanks, and toss out the d messages like tickets from a cash register. The chain of mechanisms will be completed by an automatic folding and envelop machine, which will fold the telegrams and thrust them into tra parent envelopes and seal them so that only the addresses will sho through.

The printer, two views of which are shown in Figs. 25 and now driven by a small motor consuming about 40 watts for a sp of 140 words per minute. This motor also supplies the power automatically returning the typewriter carriage to the beginning new line. Fig. 27 is a general view of a set or "station" of apparatus. Only one keyboard perforator is shown; but in pract three or four are needed.

CAPACITY OF THE MURRAY SYSTEM.

The speed of the printer is now not less than 900 letters words) per minute, and the automatic portion of the mechanism perfectly up to about 200 words a minute. Unfortunately, how no typewriter yet constructed will stand the strain of more than 720 letters (120 words) a minute in continuous service. The rece tape may be divided into sections and run through two printers the apparatus has to be worked at top speed. Under existing tions, however, high speeds for handling commercial messages many reasons undesirable, and a maximum of 120 words a mi in each direction seems to meet all requirements.

In practice with the Murray system—as with all other teleg systems from the Morse key upwards—the average output is not than about 50 per cent. of the maximum. Time and patience doubt stop some of the leaks; but others, such as errors caus line interruptions, seem to be incurable. The British Post Office now had the Murray apparatus in use for seven hours a day for eighteen months between London and Edinburgh, handling ordi commercial telegrams, and the German Post Office has been giving prolonged trial between Berlin and Emden, and is now equipping circuits with the improved apparatus. The Russian Post Office ha decided to give it a trial, and has ordered Murray apparatus to two circuits. In this case one of the conditions is that the system transmit Latin or Russian characters at will. I understand th experience of the British Post Office is that five operators at each of a Murray circuit, equipped with the apparatus in its original can exchange about 200 telegrams an hour, and under favo circumstances occasionally as many as 240 per hour. With the motor-driven printer, with automatic line feed, invisible correct errors, and other improvements, it is estimated that it will be for six operators at each end of a Murray circuit to exchange abo messages an hour. That is to say, twelve operators on one circuit will be able to do the work of sixteen men on two Morse ruplex circuits, or at lower speeds eight operators will be able the work of twelve. Actual tests show that the improved prin a maximum speed of five messages a minute, so that the

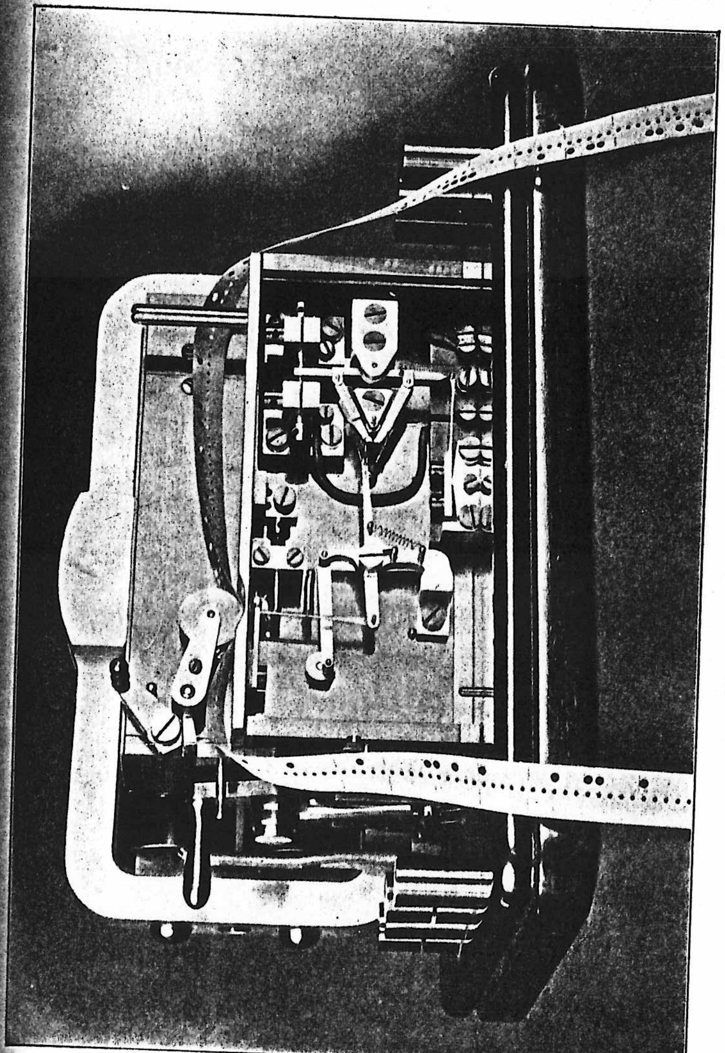
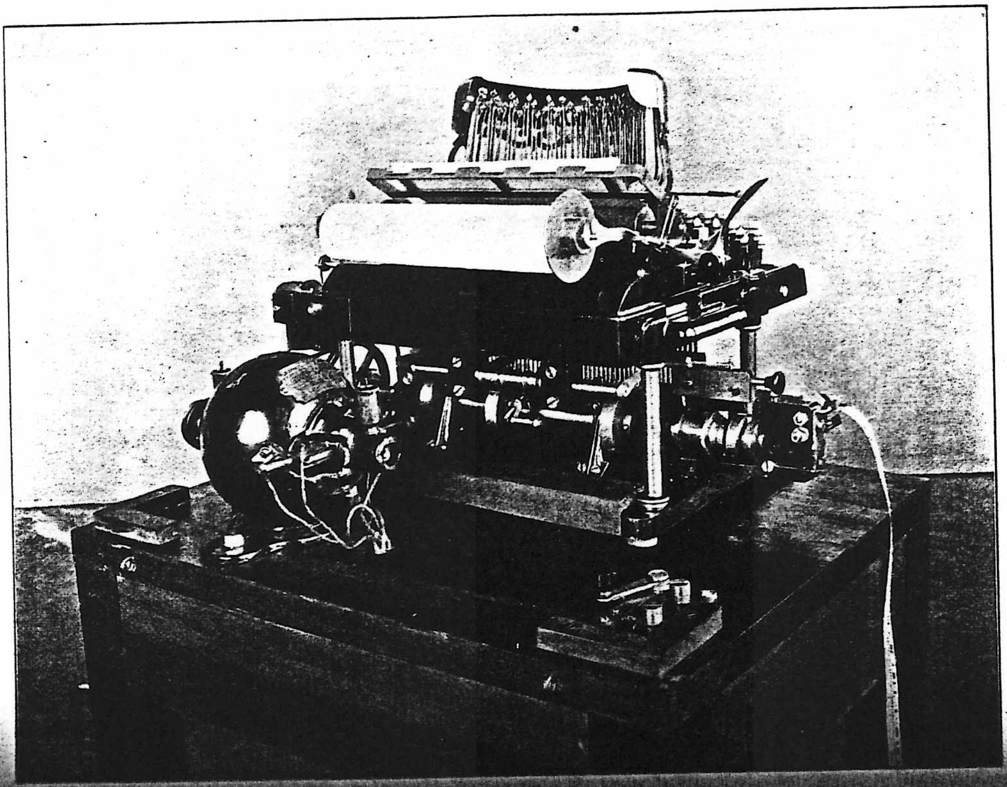


FIG. 21.—Single-line Transmitter.



[illegible]

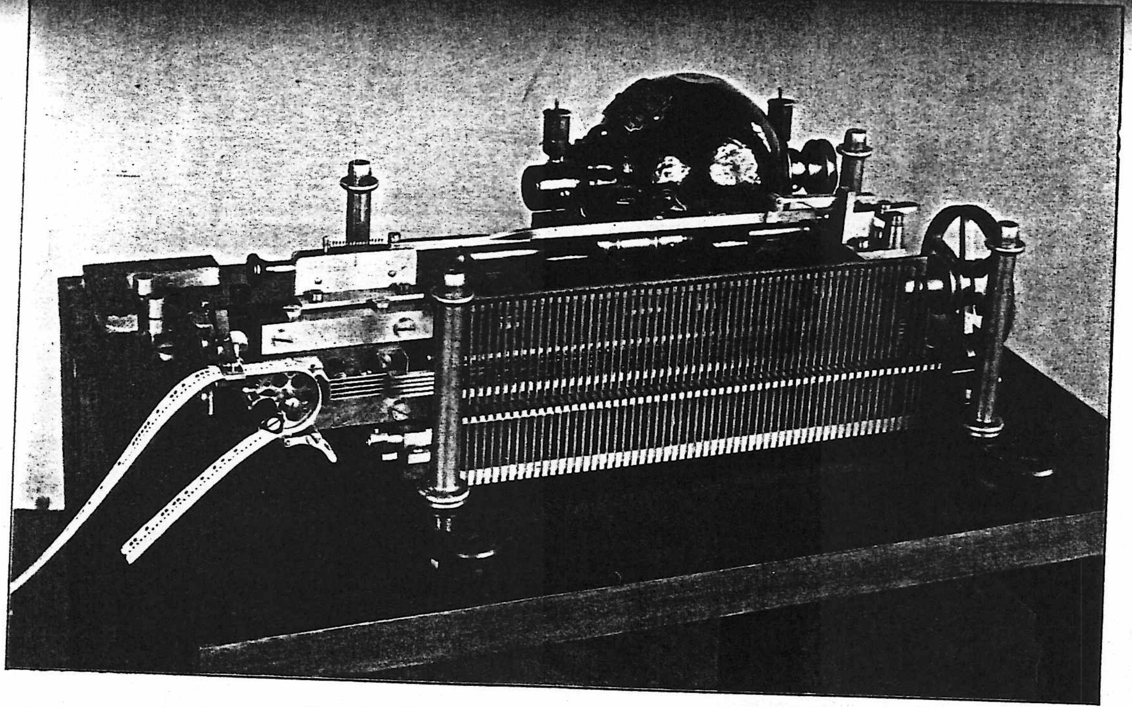
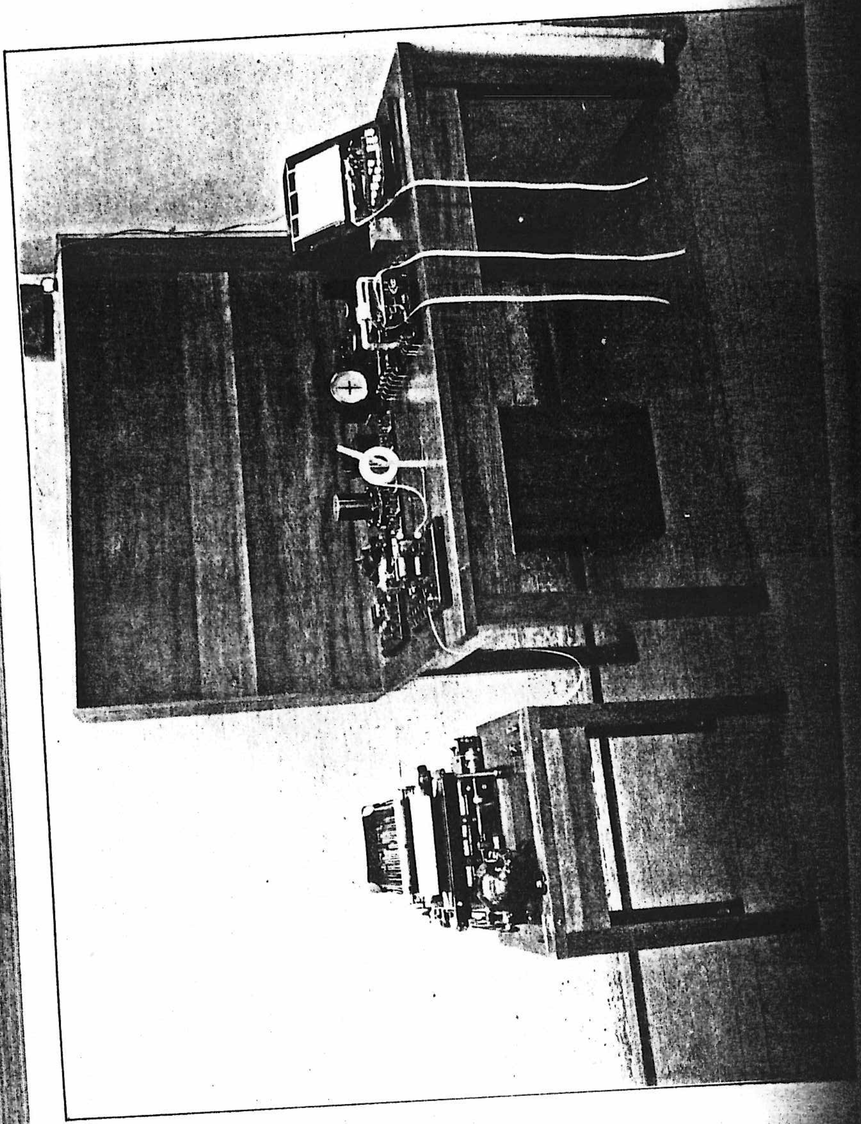


FIG. 26.—Murray Printer with Typewriter removed.



erage may be safely put at 150 messages an hour. A weak point
ith many printing telegraph systems is durability. I understand that
this respect the Murray apparatus has proved satisfactory.

Automatic Typesetting by Telegraph.

Mention has already been made of the fact that the Murray printer
s originally designed, not for telegraphy, but for automatic type-
tting in the ordinary sense of the word, the idea, inspired by
spaper experience, having been to operate a linotype automatically
means of a perforated tape produced by a typewriter keyboard.
eral machines of this kind are in successful operation, notably the
ston Monotype. But of these inventions the Murray is the only
that has been designed on lines permitting of successful telegraphic
elopment. In fact, in the case of the Murray apparatus the
graphic development has been so successful that it has quite over-
dowed the original typesetting idea. Three years ago the Linotype
pany in New York offered to carry out the experimental work
lved in applying the Murray key-selecting mechanism to the
type, and want of time alone, owing to telegraphic developments,
vented me accepting that offer. It is obvious that it is just as easy
operate a linotype keyboard automatically by telegraph as to operate
keys of the typewriter used in the Murray printing telegraph
tem. No doubt this will be done in time, but the labour saving will
be very great. The cost of setting a column of news matter by the
type is roughly about 3s. 6d. The automatic mechanism would double
speed, but, as an attendant would still be needed, there would only
saving of labour of about 1s. 9d. per column, or a saving of only 15s.
0s. per night even for large newspapers. This would hardly be
cient to induce newspapers to start automatic typesetting by
graph, but the possible saving of time is a more important
ure. The saving of a few minutes is vital to newspapers at certain
s, and this may ultimately lead to automatic typesetting by
graph; but there are many obstacles in the way. One is the
ssity for press messages being revised, punctuated, corrected, and
n cut down before being set up in type. The Murray is the only
matic apparatus making provision for this difficulty by allowing the
rial corrections to be carried out by the compositor while the type
ing automatically set. All that can be said about automatic type-
g by telegraph is that it is a possibility of the future, and that if it
one at all it will have to be done on the lines of the Murray
ratus, because the Murray system alone is practical both from the
paper and from the telegraphic point of view.

Typewriting Across the Atlantic.

nother interesting possibility, with better prospects of early
vement, is printing telegraphy in connection with ocean cables.
has been rendered possible by the Murray apparatus in conjunction

with Mr. S. G. Brown's beautiful cable relay and perforator, and the Cooke alphabet shown in Fig. 8. A sample of this alphabet, perforated in a piece of automatic cable tape, is shown in Fig. 28. As this is an equal-letter alphabet it can be perforated in cable tape by a slightly modified form of the Murray keyboard perforator already described, and this tape can be transmitted in the usual way through an automatic cable transmitter. About two years ago the Eastern Telegraph Company used some tape that I had prepared with this alphabet to transmit from Porthcurnow, and no difficulty was found in reproducing the tape at Gibraltar by means of the Brown relay and perforator. The length of the cables from Porthcurnow to Gibraltar is 1,190 nautical miles (about 2,160 kilometres), and the KR of the cable used is 2·8 millions. A slightly modified form of the Murray printer has been designed to print from this tape. Six combs are provided with rods projecting alternately above and below to engage with the message holes on both sides of the tape, and there is a seventh figure-shift comb. Not only is this arrangement perfectly practicable, and the instruments all known to work well, but it has the advantage that, as the alphabet is about 10 per cent. shorter than

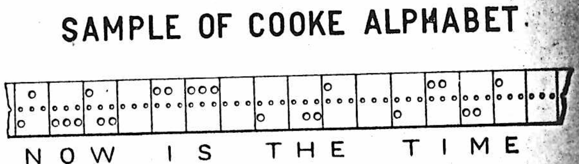


FIG. 28.

the cable Morse alphabet at present used, the carrying capacity of the cable is increased, roughly, about 10 per cent., a considerable gain when dealing with such an expensive investment as an ocean cable. It will also be noticed that fourteen of the most frequently used letters in this equal-letter alphabet are the same as Morse. Those accustomed to Morse cable tape will notice that the sample of tape in Fig. 28 can be read without serious difficulty, only one letter, H, being different from the Morse. With such a world-wide business as that of the Eastern Telegraph Company there are difficulties in the way of introducing the Cooke alphabet, but in the case of the Atlantic cables these difficulties do not exist. There is no technical obstacle in the way, and it is undoubtedly practicable with the aid of the Murray keyboard perforator, the Brown cable relay and perforator, and the Murray printer to work a typewriter in New York by playing on a keyboard in London. It is also possible by the same means to operate a linotype in a New York newspaper office by playing on a keyboard in London. For commercial reasons the possibility of automatically setting type across the Atlantic can never be of practical importance, but typewriting across the Atlantic is well within the bounds of utility, and want of time is the only reason why it has not

been attempted. In fact, there are so many possible developments of the Murray apparatus that it has been impossible for one man unassisted to attend to them all.

A Brief Comparison and a Few Words About the Cost.

Putting aside these possibilities and returning to the subject of telegraphy on land, it seems to me that the Murray automatic system is pre-eminently adapted for long-distance work, iron wires, underground cables, and press dispatches. Its power of retransmission from the received tape, its high speed, its simplicity, and its provision for instant and invisible correction of errors, appear to make its position fairly secure for the classes of work just mentioned. But for short-distance traffic the multiple principle certainly will have a number of advantages when developed so as to save labour. This is the weak point with the multiple systems at present. They do not save labour. Of these systems the Baudot is, to my mind, undoubtedly the best. Like the Murray system, it is constructed on true scientific lines that permit of further development and adaptation to the needs of various countries. It works well through cables and over considerable distances (thanks to the Baudot alphabet), but its chief limitation, in addition to printing its messages on tape, is the use of synchronism, and for isochronous working over long distances it uses two wires, while the Murray uses only one. For short distances the theoretical capacity of the Baudot is enormous, probably not less than 5,400 letters (900 words) per minute—direct type-printed messages—but in practice not more than six transmissions at 30 words a minute each are attempted, giving a maximum of 1,080 letters (180 words) per minute. It is used on all the busy circuits in France, and Paris is connected with London, Hamburg, Berlin, Vienna, Rome, Milan, and Algiers by means of Baudot apparatus. Several sets are also in use in Brazil and in French Indo-China.

A large amount of inventive talent has been devoted to the Rowland multiple system, and I have no doubt that the clever engineers connected with this interesting apparatus will continue their improvements. Being a direct-transmitting page-printer, errors cannot be corrected without showing on the printed message, and the Rowland alphabet bars it from use on underground cables and for long-distance traffic. Its potentialities, however, for handling short-distance traffic are considerable. Its maximum speed is about 1,800 letters (300 words) per minute, duplex, over moderate distances; but so far, with the Rowland, as, indeed, with all other telegraph systems, including even the Morse key, there is a large gap between promise and performance. The Rowland system was tried and rejected by the British Post Office about three years ago. Since then several sets have been on trial on the Continent.

The Buckingham automatic system cannot retransmit like the Murray, that it cannot cover such great distances nor retransmit news so conveniently to a number of centres. It does not correct errors so efficiently, is not so rapid, and it is much more complicated; but it works very well over long distances of 1,000 miles (1,700 kilometres) duplex, giving a maximum speed of about 100 words a minute in each direction, and the mechanism employed is remarkably ingenious. It has been in commercial use by the Western Union Company in America for several years past, and it was tried and rejected by the British Post Office during the winter of 1903.

A very attractive scheme for high-speed printing telegraphy is the use of light and photographic paper for the printing process; but the systems employing this method have not yet got beyond the interesting stage. The Siemens & Halske photo-printing telegraph is the best up to the present, and it reaches a speed of 2,000 letters a minute in one direction, but the messages come out recorded on a damp photographic tape, an arrangement that does not seem very promising from a practical point of view.

The cost of the multiple and automatic high-speed systems of printing telegraphy may appear at first sight to be very high if we compare it with the cost of the Morse key and sounder, or with a Morse quadruplex set, and it is this comparison that telegraph administrations in English-speaking countries have habitually made, wrongly, as I believe. A Baudot sextuple outfit to equip both ends of one circuit costs, it is stated, about 20,000 francs, or, in round numbers, about £800. A complete outfit of the Murray system costs about the same at present, though it is expected that the cost of manufacture will be reduced when sets are made in numbers. In regard to the prices of the Rowland and Buckingham systems I have no information, but they can hardly be less costly than the Murray and Baudot. In any case, taking £800 as the cost of an automatic or multiple system, this is less than the cost of two linotypes, of which at least a score are to be found in most large newspaper offices. I understand that the French Post Office does not possess more than about 250 sets of the Baudot system. Many of these are only for double and triple transmission, so that even if we take the cost at as much as £300 per set (that is to say, equipment for one end of a circuit only) the total cost, apart from the cost of development, has only been somewhere about £70,000, a very small sum for such a large business as a telegraph administration to spend on special machinery that, at a cost of from £600 to £[illegible] per circuit, will save a capital expenditure on wire, at £12 per mile, of from £2,000 to £12,000, compared with the Morse quadruplex; and that will, in the case of the Murray system, at any rate, save about 25 per cent. in labour compared with the Morse key and sounder.

CONCLUSION.

It has not been possible in this paper to do more than refer briefly to the special conditions to be fulfilled by successful printing telegraphs, to the relative advantages of the multiple and the automatic systems, the advantages and disadvantages of direct keyboard transmission and of indirect automatic transmission, the relative merits of the typewriter and other keyboards and keys, speeds of keys and keyboards, and the advantages of machine compared with hand

telegraphy; but there will no doubt be opportunities of dealing with these points in the technical journals at some future time. Nor has it been possible to touch upon the practical difficulties which have been encountered, chiefly in connection with page-printing. To enumerate only a few, there are special page-printing telegraph difficulties in handling short commercial telegrams, practical working difficulties arising out of line disturbances, checking, and corrections, difficulties based on the necessity for following the ordinary telegraph routine, which varies in each country, and difficulties connected with the use of suitable telegraph forms and preserving records of messages. Many of these difficulties are so small and impalpable that even men who have grown up in the telegraph profession have failed to recognise their existence until actually confronted with them. Their invisibility, however, has not made them any the less formidable, and the fact that they have been overcome is due to the cordial co-operation, advice, and assistance freely given by the telegraph officials in America, Great Britain, and Germany. The Postal Telegraph Company in New York and the Telegraph Administrations in London and Berlin have devoted to the Murray system not only time and money, but the best technical skill of their engineering staffs. And the results, I hope and believe, will prove satisfactory to all concerned.

DISCUSSION AT MEETING OF MARCH 2ND.

Mr. Gavey.

Mr. J. GAVEY: I think we have all read Mr. Murray's paper and listened to his explanation of the working of his apparatus with a great deal of pleasure. His paper is very valuable, not merely from what it tells us, but from what it suggests. In view of the statement that he makes of the plethora of printing and writing telegraphs that have been invented and described, it will no doubt occur to members present to ask how it is that after so many years of telegraphic work the principal telegraphic administrations still use the old-fashioned Morse for the greater portion of the telegraphic business of the world. There are various reasons for that. Mr. Murray has given us some; amongst others he states that the Morse alphabet is *per se* the ideal alphabet for manual transmission. But there are other reasons which have prevented so far the general use of machine telegraphy. The telegraphic public have been educated to a high degree of speed, and they demand the same rapid rate of delivery whether a message has to be transmitted over two or three miles or over hundreds and thousands of miles. Not only does a man in Glasgow expect his message to be delivered in London as quickly as a man in Westminster expects his to be transmitted to the City, but a New York man expects the same speed to London. The result is that there is a tendency to discourage any operation that intervenes between the receipt of a message at the counter and its passage over the wire, and again at the far end between its reception and its being handed over to a delivery messenger. The effect is that most telegraphic administrations have considered the ideal system to be a manual system, involving the use of the simple Morse key, in which the messages are brought up to the instrument at the forwarding station and despatched over the wires, while at the

Mr. Gavey. receiving station they are written off direct, packed in envelopes, and sent out without any intervening operations. It has always been recognised that although this may be an excellent system for the rapid transit of messages, it is rather costly in the sense of the capital involved in the erection of numerous lines. That difficulty has been got over in a measure by multiplying the channels available on each wire, by duplexing, by quadruplexing, and by other methods. I observe that Mr. Murray does not like the idea of the quadruplex method. I need not say we all know that the B side, the increment side of a quadruplex system, is always the weak portion of that system, and that when troubles arise from bad insulation or other faults with which the telegraph man has to contend, the B side is the side that always fails. I may add, however, that we have had a very marked measure of success in the use of quadruplex working on our new underground lines which are now being laid, and are rapidly approaching completion, between London and Glasgow. The more important of these wires had to be laid up in loops; in fact, the design was similar to that of a telephone cable, because we knew there would be a large amount of mutual induction, static and magnetic, between neighbouring wires if they were worked as single wires to earth. We provided loops, therefore, for all main circuits, and we have adopted the following method of working so as to get as effective a service out of the metallic loop as we could out of single wires. We generally put a high-speed Wheatstone or a quadruplex circuit on a loop, and we superimpose on them a duplex circuit, so that we are able in that manner to get six channels out of two wires. That is one method of effecting economy, and there are others which I need not refer to now. When we come, however, to one of the important functions of the Post Office, the transmission of press matter, there machine telegraphy has not only been generally used, but I have no hesitation in saying that the work of the country could not have been carried out without it. At least two millions of words have to be transmitted over the Post Office wires every night, but without the machine telegraph known as the Wheatstone system it would have been utterly impossible to deal efficiently with the amount of news handed in every evening. The Wheatstone system is an admirable one so far as the transmission is concerned. The reception has always to my mind been the weak portion. Work can be turned out at three or four hundred words a minute, but at the far end it is necessary to employ a large staff to write out laboriously from the record slip. When I heard first of Mr. Murray's beautiful system it struck me that therein lay the hope of the economical distribution of our news matter, as well as perhaps an improved method of dealing with ordinary public messages.

With reference to the other systems, we are always experimenting with various types of instruments at the Post Office. In the last eighteen months we have carried out experiments with the Rowland telegraph which Mr. Murray refers to, which was exhibited in Paris and was briefly described by me in a paper read shortly after the Exhibition. We have tried the Buckingham; we have tried the Mercadier, in which they profess to send twenty-four messages simul-

taneously on one wire; we have tried the Pollak-Virag, in which a punched slip is reproduced, not in typewriting, but in actual cursive characters, and we have also tried the Creed and the Murray. Mr. Murray's is a beautiful system, and all I can say is, that I hope it will be as successful as it promises to be. Perhaps the feature in Mr. Murray's apparatus which has struck me as being the most novel, and certainly which I have appreciated very highly, is his extremely ingenious method of obtaining asynchronous running between the transmitting and the receiving apparatus. His method of placing spring buffers at the extremity of the vibrating reed, and thereby admitting of regulating the speed by varying the current due to clipping the signals, is a beautifully designed piece of apparatus, and in itself I must say it struck me as one of the prettiest and most novel features of the whole design. Mr. Gavey.

Mr. H. LAWS WEBB: Mr. Murray has, I think, covered the subject very broadly and very deeply. I have marked three or four points that occurred to me in the paper as being of interest to discuss. Mr. Murray says on page 557 that the fundamental distinction between the telegraph and the telephone is in the simplification of signals. In the long run the proof of the pudding is the eating, and the fundamental commercial distinction between the telephone and the telegraph is that the telephone gives you direct communication between the speaker and the listener without any intermediary apparatus or transmission or operation, such as Mr. Gavey has described, of taking the message to the operator, and of sending it out again, and so forth. That is the whole point in the difference between the telephone and the telegraph, and that is the reason why the telephone has completely outdistanced the telegraph, in point of volume of business done, within a very few years. You will find that in long-distance telephone service, in spite of the heavy wire cost which long-distance telephony involves, and in spite of the high cost of using it, journalists, who are very acute business men, use the telephone for transmitting their messages, because they find they can get more work done in a given time and at a lower price by the telephone than by the telegraph. With regard to the question of telegraph alphabets, Mr. Murray states with absolute certainty that he has the best alphabet, so there is no need to discuss that question. The question of errors is a very important point. Mr. Murray described, on page 577 I think it is, how the perforating operator can correct errors, how a typewriter operator in every page makes some mistakes, but he has consciousness of those mistakes in the making of them, and can rub them out. With the ordinary typewriter of commerce I find a good many mistakes occur that the operator has no consciousness of at all, and I have no doubt the same must occur in perforating telegraph messages. Therefore some errors get through to the receiving instrument before they are noticed. It would be interesting to know how the received errors are taken care of. I have studied the paper pretty carefully, and I do not find that point described. Errors must naturally occur, in any telegraph system, that do not go out to the line on the tape, from "kicks" on the line, and from impulses getting shortened or lengthened, which must appear as errors on the receiving instrument. I think that Mr. Webb.

Mr. Webb.

is a very practical point; it would be interesting to know how the actual received errors are dealt with. Dealing with the key-board perforator, on page 579, although Mr. Murray is an authority on the subject, I think he hardly does justice to the actual possibilities of key-board perforators for telegraph work. The Buckingham key-board perforator, which is an electrical perforator, producing letters of unequal length, has absolutely displaced in the New York offices of the Western Union Company all the mallet punches formerly used for Wheatstone work, because it is found that the capacity of the operator is so largely increased. My recollection is that they find an expert operator can perforate messages at the rate of about 80 words a minute on the Buckingham perforator. I fished out a record of one man's work there. It shows in 152 days a total of 47,708 messages. That is one man's work on a key-board perforator with Wheatstone working—an average of just under 314 messages a day. On some days this gentleman's work went very much over the average. On some days it reached 600 odd messages, and on one day 700 odd, and there were numerous days with over 500 messages. The American message averages a good deal longer than the English message, for the reason that the custom there is to give the address and the signature free, and people therefore write ample addresses and very often full signatures, so that the average number of words is considerably more than in the average English message. I do not wish to make any captious criticism, but I think it would have been better, since Mr. Murray is so convinced that he has the best alphabet and the best system, if he had left aside other systems and confined his description to his own, because there are one or two remarks here that other people might reasonably object to. It is said the Buckingham system was tried and rejected by the British Post Office during the winter of 1903. It certainly was rejected, but opinions may differ as to how far it was tried. Mr. Murray has said that his system has been tried by the Post Office for eighteen months, but I think he would not be far wrong if he doubled that time. The Buckingham system was actually tried, in steady work with the Post Office employees, for something like eight weeks, and the trial was stopped before the operating staff had fairly a chance of getting hold of a new system. Of course the trial of a new system like that might reasonably last a good deal longer to find out its weak or its strong points. It is natural to imagine that an operating staff would have a certain amount of difficulty in picking up the working of a new system, so that I do not think that constitutes a very thorough trial, although I can quite understand that the Post Office, which was already experimenting with the Murray system, did not wish to carry on very long experiments with the two. It is no good trying to flirt with two people at the same time. I quite agree with Mr. Murray's remarks on page 596 that the capital cost of the apparatus for working a high-speed printing system is of very small consequence when you consider it in comparison with the capital cost of the lines and the amount of labour which it saves. I quite appreciate the theory that Mr. Gavey has mentioned in explanation of the Post Office system of hand working, that what people want is very rapid transmission; they take no

account of distance, and demand a minimum amount of delay, regardless of distance. But I have not the slightest doubt that with proper organisation in the handling of the messages, commercial messages could be transmitted just as quickly by an automatic machine system as by hand.

Mr. Judd.

Mr. W. JUDD: I have had the pleasure of knowing Mr. Murray for some years past, during the time he has been carrying out his experiments, and have had the pleasure of very many interesting conversations with him, in which he has shown what is obvious and manifest in his apparatus, the originality and ingenuity which he has brought to bear on his task. One of the things that interests telegraph and cable people is this question of alphabets. It is almost impossible with any large system of telegraphy to tamper with your alphabet. If you do, it will be very much the same as if our President were to decree that our discussions here were to take place in Volapuk. I think I remember that in a certain colony not very many years ago it was determined to introduce the international code in place of the original Morse code. Whether they succeeded or not I do not know, but I believe a rather chaotic period intervened. I think that before altering the alphabet on any large system we should have to consider the matter very seriously. In connection with his alphabet, Mr. Murray suggested to us the use of Mr. S. G. Brown's cable relay and receiving perforator, by means of which we should punch out a slip with his alphabet at the other end of a long cable, pass it through a transmitter, and so repeat the operation until we get to the other side of the world. This would be a comparatively simple thing if we had a separate cable for every country; that is to say, if we had a straight through line from here to the Antipodes, but on lines where there is way traffic coming in and going out at all sorts of intermediate stations, we are confronted with the difficulty, which all telegraph men will understand, of the running message, or check numbers for each circuit. The message would start with a London number, and it would naturally have under that system to carry that number right through, because of the copying effect of the apparatus. It would be impossible, therefore, transferring from one circuit to another with all sorts of intermediate numbers coming in on it, to keep any control over the traffic, and, of course, a lost message is the unpardonable sin in any telegraph service. These difficulties may seem small, but Mr. Murray has indicated in his paper that they become important when they have to be definitely faced. We are very much interested in the question of key-board perforator speeds. We have a model of our own which will be in use before very long, and the question of speeds to be attained on it is naturally somewhat interesting. We have tried it on ordinary typewriters, with our most expert typists, who could rattle away in a very imposing manner from a newspaper or from any plain writing, but when the hideous code words that the public inflict on us now have to be dealt with, the expert typist goes to work with one finger like a novice on a piano; so that when the last speaker told us of the operators in New York attaining a speed of 70 words a minute I felt very distinctly relieved. I only hope that we on this side of the Atlantic will be able to do as

Mr Judd.

well. There is one difficulty with all these improvements that are brought to the notice of any large submarine telegraphic enterprise. Improvements are desirable, of course, but the great distances, and climatic and other influences present certain difficulties. Still, we are always trying to carry out improvements, and are only too willing to hear of them. As far as the cable interest is concerned, I am bound to say that a great many of the improvements have come from outside our own circle, as is the case with Mr. Murray and Mr. Brown, our gold medallist of last year, who are outside the telegraphic ranks, and who are therefore not running in a groove as some of us have done for the last thirty or forty years. They come in with fresh ideas, scorning the limitations which we have put before us, succeed sooner or later in showing us that there is something outside of our own groove which is well worth our attention. That is very largely so in the case of the enormous amount of research and work in regard to alternating currents, magnetism, and self-induction. We rather thought that these things had nothing to do with us at one time. We have long since learned to see that is not so, and we have found that we can make use of these improvements and discoveries as well as anybody else. I think that is the principal advantage of an institution like this. It is not a meeting of traders who have axes to grind; it is a meeting of people who endeavour, each to the best of his ability, to advance the cause of the science in which we are more immediately interested, and in that way I think the Institution does more to spread abroad the knowledge we are all wanting than any other institution in the country.

Mr. Higgins.

Mr. F. Higgins: I have been very much interested in this system for telegraphing with type at a distance. I think it will be extremely useful for long lines; but in the case of the business with which I am connected I can see that it would not be of any service whatever, because the operator preparing the message at 20 words a minute —which I think is an exceedingly low rate—would be far behind our operators, who send it out and deliver it direct at 30 words a minute. In the case of the City of London, we sometimes deliver messages between Ludgate Circus and Temple Bar to the newspaper offices on about six or seven lines at the rate of 5,000 words a minute; but Mr. Murray's apparatus would not assist us at all in getting the news out promptly. The initial delay in preparing the message and its translation at the end would delay the publication of news in the various editions of the newspapers and make this service rather a slow one compared with the present, which is altogether slower apparently in transmission than the Murray, but we multiply the number of wires to increase the rate of delivery. We have a wire for each separate service, and an operator transmits the messages as they are handed in direct without any previous preparation. They are received in the newspaper offices in Roman characters, which require no further translation. They are handed direct to the compositors, and in some instances the messages are delivered to the public within a few seconds of their having been delivered on our tapes. But for long-distance telegraphy, where the cost of wires is a very important consideration, I have no doubt that this interesting system might be of very considerable service and ultimately displace the Wheatstone, which will some day perhaps become obsolete.

Mr. Higgins.

Mr. Sayers.

Mr. H. M. Sayers: I do not think this discussion should close without an appreciation of the admirable way in which Mr. Murray's paper has been written. It is a model and an example of logical and orderly setting out of a beautiful invention. Both as regards the mechanical logic—if I may invent a phrase—and historical sequence the paper is an exceedingly interesting one. I do not think a better paper as regards style and arrangement has been read before any scientific institution for many years. I was interested in what Mr. Murray said to-night about the punching speed, because I was once a Wheatstone puncher myself. In those days the Wheatstone was the fastest instrument that was in use in this country. It had not then attained the speeds which have been reached in recent years, because iron wires were still in universal use, and we thought we did very well if, with fine weather throughout the whole of the line, we worked from London to Glasgow at 100 words a minute without a relay. The Wheatstone perforator is capable of 25 to 30 words a minute when a good operator has a continuous flow of work; 40 to 45 words a minute is easily done on press work where one gets sheets of 100 or 120 words each. The Wheatstone perforator has only three keys. There is no need to look at the keys at all; one could punch at full speed in the dark if the message were dictated to him, except for the fact that a good puncher keeps an eye on his slip. He can read both copy and slip faster than he can punch so that the process of looking out for errors, always considered an exceedingly important one, in no way interferes with the rapidity of punching. If with a Wheatstone puncher, in which one has to compose his letters in the Morse alphabet, 30 words a minute is a commercial speed, it seems to me that with the Murray or other key-board instrument operators with sufficient practice ought to be able to reach a speed of from 80 to 100 words a minute. Whether they can punch at that speed, and also keep an eye upon the slip is another question; that will only be answered when the apparatus gets into regular use. A Wheatstone operator does not reach 40 words a minute with six months' practice; it takes some years to get up to that speed. A good Hughes operator can send 50 words a minute, but with more key positions, and combinations as well, to learn, takes rather longer than a Wheatstone puncher to attain maximum speed. In the Hughes case there is, however, an instrumental speed limit. There is another point that strikes me as historically interesting. Mr. Murray mentions the possibility of a "space" alphabet. I wonder if he remembers that the old Cooke and Wheatstone five-needle instrument had a space signal alphabet. Each letter was indicated by the simultaneous movement of certain of the five needles, so that the alphabet was formed by space signals and not time signals. That is an interesting fact which may be added to Mr. Murray's collection of telegraph alphabets.

Mr. Mudford

Mr. F. J. Mudford: Some twelve or fourteen years ago I was interested in a telegraphic type-setting machine, the practical side of which I worked out. I have therefore been very much interested in

Mr. Mudford.

Mr. Murray's paper and in the apparatus which he has shown us to-nig I would like to make one or two suggestions which may be useful t him or to others. He mentioned the noise that the instrument ma By hanging the vibrating reed on rubber cords he will scarcely he the reed working. He will also find that with the La Cour or pho wheel he would get a saving by having two series of magnets in ea case opposite each other, used so that the pull came exactly opposite th spindle. We found that the tug on one side was very strong inde setting up a considerable vibration and also interfering with the ca with which the wheel revolved. We found there was a considera saving by having a magnet on each side. In Mr. Murray's case the would have to be two series of magnets, because one has to be a ha tooth behind the other, so that he would have to have four magne Mr. Murray has got over one little trouble that we experienced, b doing away with the second revolving wheel that we used for o apparatus. We actually set type with our instrument between King Cross and Holloway. Our revolving wheels ran at about 250 revolutio a minute, which brought us into the difficulty of a very small amount o time to deal with the contact. We got over that, strange to say, b having two contacts instead of one for each signal, and by having system of intersections somewhat similar to what Mr. Murray has do in his printing machine. We had, say, twenty-eight working segment and we had to operate two of these for each signal, so that with 24 + contacts we could get four times twenty-four signals. We had the fore a very much longer time for the electrical operation of the relays Another difficulty we had, which it might be of interest to some pres to mention, was the operator keeping down the key too long. In th case he would send a repeat signal at the rate we were going. Th led to the designing of a little apparatus which would break the con nection when the signal had passed. On the depression of a key battery contact was kept closed by an armature being held down b the soft iron extensions of a permanent magnet, but contact to the seg ment was only completed when the key was raised and the armatu free to rise on the passage of a current to line which depolarised th extensions.

Mr. Adams.

Mr. A. J. S. Adams: Perhaps one of the more important advantag of the Murray system has been overlooked in this discussion. If a Morse slip be handed to an operator for transcription, much wi depend upon that operator, and, to put it mildly, his state of health but with the Murray, directly a telegram arrives it is ready in Roma type, and all that remains is to tear it off and deliver it—a fact which seeing that time and labour are money, should mean a great deal.

Mr. Murray.

Mr. Donald Murray, in reply: I think one of the chief poin mentioned in the discussion was the question of speed on the ke boards. That is the very essence of printing telegraphy from a practical point of view. If that speed is not superior to the speed wi the Morse key or some other methods of transmission, then printi telegraphs are useless. As a matter of fact it is superior. The sp possible on a keyboard is quite high; but when an operator has t sign and time short messages of twenty words, has to pick them up an

Mr. Murray.

ay them aside, and do other little operations like that, the time lost is urprising. Mr. Webb mentioned the Buckingham system. I have ome records of the work of the Buckingham keyboard perforator, and hey are wonderfully good. One man, I was told in New York, unched 770 messages in $7\frac{1}{2}$ hours, that is 104 messages an hour. But e must not take the maximum speed of the maximum operator; we ust be guided by the average speed of the average operator. That s the only thing that is of any practical importance. Mr. Webb entioned the case of a man who, for quite a long period of time, 152 ays, had done no less than 314 messages a day. That is very good; must admit it is better than I had expected. Nine hours a day is the sual time that American operators work, one hour of which may be egarded as slack time. Therefore, if you divide the 314 messages by it gives you 40 messages an hour, and 40 messages an hour is not uch better than good Morse key operators do in America. Thirty essages an hour is what they do here, and the messages are considerbly shorter. If we multiply 40 messages an hour by 30 words for the erage American message, and divide by 60, we get 20 words a inute. That is the average work of a good operator taken over a nsiderable period. The Morse key operator under similar circumances will not do more than 10 or 12 words a minute when he has to n the messages, and perform all the other little details. There are o times when business is slack. Sometimes there are no messages the operator to go on with, and he has to wait. That is all included. at is the kind of speed I mean when I say 20 words a minute— luding all the little incidental delays, signing and timing messages, ring off the tape, rolling it up, and passing it on to the transmitter. that cuts down the average speed. Taking everything into coneration, however, there is a considerable margin between the keyrd perforator and the Morse key. Morse key operators in America e attained a speed of 50 words a minute in short speed contests, d there was one very interesting tournament in which a group of le and a group of female picked operators competed. The female rators averaged 39·4 words a minute on the Morse key, and the le operators 43·5 words a minute, a very interesting result from ny points of view, social as well as telegraphic. But these were ked operators; and that was their maximum speed, and much yond what they would achieve in ordinary telegraphic practice. Gavey made some remarks about the quadruplex, which reminded that there is one point I have not made quite clear in the paper. point I wish to make about printing telegraphs is that they can be rked with any method of transmitting signals. A quadruplex is ly a method of transmitting signals over a line; a printing telegraph system, it is not a method. A printing telegraph system can be ked by the duplex or the quadruplex method, provided you have a ciently good quadruplex; but the weakness of the quadruplex s in, and I do not think it would be worth while. The Murray m may be worked on the first side of the quadruplex, and the d side may be used for getting corrections and repetitions and ing messages by hand if desired. There is no competition between

Mr. Murray.

a quadruplex and a printing telegraph. That is rather a mistake on my part; I should have made it clear in the paper, and Mr. Gavey has done well in calling attention to the point. I noticed that several speakers referred to synchronism, although I have drawn special attention in the paper to the fact that there is no synchronism between the two stations in the Murray printing telegraph. There is isochronism. It is quite an important distinction. If you only have speed to consider and not phase it makes a great difference. Reference was also made to the question of the correction of errors, and it was pointed out that many errors pass unnoticed, but in designing the correcting device it was not so much the correction of errors that was aimed at; the aim was to give the operator confidence, and therefore speed on the keyboard. When the operator knows that if he strikes a false key he can instantly correct the error, he can work more confidently and therefore more quickly. There is a saving of labour, and the operator can do more work without working harder. Of course, the correction of errors is in itself very important, and the human being does make unconscious errors, and such errors he cannot correct. To put the argument in another way, I might mention that medical men have frequently called attention to the remarkable analogy between the human brain and a gigantic system of telephone exchanges. It has been estimated that there are no less than 3,000 million nerve cells, or to follow out the metaphor, subscribers, in the human brain, and the network of nerves or wires is past all conception. What the human operator has to do is to make his connections in his brain correctly. It is a very curious fact that any one who chooses to keep a note of the errors he makes in writing, will find that most of his mistakes are mistakes of switching. As he writes, he thinks of the words or the letters ahead, and it will generally be found that the mistakes are transpositions of letters, especially when working on a typewriter. The mind is conscious of most of this stumbling the moment after it occurs, and it is to enable the operator to overcome this trouble that the keyboard is provided with a correcting mechanism. Mr. Judd mentioned some points about cable work. This is very important for the future; but I agree with him that it will be some time yet before we get printing telegraphs working on cables. With a complicated and world-wide system like that of the Eastern Telegraph Company, it would, of course, be exceedingly difficult to change from the Morse alphabet, but it is possible to modify the Murray printing machines in several ways so as to enable them to use the Morse alphabet. I have designed one arrangement for that purpose, and I think that that will be the starting-point for the application of the Murray printer in combination with the Brown cable relay and perforator to cable work. Possibly in time the Cooke alphabet may come into use, because it effects a saving of about 10 per cent. on the cables compared with the Morse, and that might be worth taking into consideration. On the Atlantic cables, there is no such objection to the use of the Cooke alphabet and a printing telegraph as Mr. Judd pointed out applies in the Eastern Telegraph Company's service. With the Atlantic cables there is direct communication between two centres

Mr. Murray.

commerce, and it is quite possible that in the near future something may be done in the direction of working the Murray apparatus in connection with the Brown cable relay and perforator on Atlantic cables. Mr. Higgins referred to the local distribution of news. The instruments for this purpose have been wonderfully developed; they are practically perfect, and there is no suggestion of competition between them and the Murray system. They have their field to themselves. There a high speed is obtainable on the keyboards because there is no timing of messages and no stopping; the operators go straight ahead all the time. On the other hand, with a system in which you have to handle ordinary short telegraph messages of 20 words, the conditions are altogether different, and the problems involved are very difficult indeed, and the solutions by no means such as one would expect at the first glance.

The President.

The President: I am sorry I had not the pleasure of hearing the paper itself, owing to the fact that I could not be present at the last meeting, but I have listened with great interest to the explanation of the apparatus which has been given us by Mr. Murray, and also to the discussion. There is only one point upon which I should like to have some further information. Mr. Judd said it would be impossible to alter the alphabet. Of course for the ordinary instrument that is quite true. There is the difficulty at present, as I daresay all of you know, that in the United States a different alphabet is used from that which is in use in this country, and this gives rise to a considerable amount of trouble. But I am afraid I have not understood the apparatus, because looking at it as an outsider, as I understand it, the sending clerk has to punch his message on the key-board on which the letters are marked, and the receiving clerk receives the message ready printed. Where does the alphabet come in?

Mr. Judd.

Mr. Judd: Only for the reason that it would be necessary very often to read the tape as it came out. Suppose the printer breaks down, it would be necessary to read the tape, and it will not do to have an unknown language on it. You must be able to read it. The alphabet on the tape is a different alphabet from that which is in use now, and it would be rather awkward to have two alphabets in the same office at the same time.

The President.

The President: I think other speakers have already explained that any system of printing telegraphs is really only practicable where messages have to go over long distances, and are in the nature of press messages. Then printing instruments are very valuable, and judging from the time I took to learn the Morse alphabet when I was young and had to do with these matters, I do not think I should take very long to learn the other alphabet if I had to do so. These instruments will always be of a special character, so that you can always have special clerks to work them. I am perfectly sure that a system in which all the signals are exactly the same length is the correct one, and makes the simplicity of the apparatus possible. In that connection I think this apparatus has quite a unique feature; at any rate, I have never seen before that the demonstrator absolutely took the instrument to pieces before the audience and put it together again—and then it

The President.

worked. That is a most important point, and that is really the correct principle for all construction. All apparatus should be made so that it can be put on a table, taken to pieces, put together again, and then made to work. As Mr. Murray said, it is the outsiders who are always inventing wonderful telegraph instruments; but all these are generally of such a complicated kind, that their adoption is difficult. The simpler the instrument can be made the better, and therefore this new alphabet which enables you to make so simple an instrument has a great deal to recommend in it.

It is now my pleasure to ask you to give a hearty vote of thanks to Mr. Murray, the author, for the very interesting paper which he has brought before us.

The resolution was carried with acclamation.

Proceedings of the Four Hundred and Twentieth Ordinary General Meeting of the Institution of Electrical Engineers, held in the Rooms of the Institution of Civil Engineers, Great George Street, Westminster, on Thursday evening, March 2, 1905—Mr. ALEXANDER SIEMENS, President, in the chair.

The minutes of the Ordinary General Meeting held on February 23, 1905, were taken as read, and confirmed.

The list of candidates for election into the Institution was taken as read, and it was ordered that it should be suspended in the Library.

The following list of transfers was published as having been approved by the Council:—

TRANSFERS.

From the class of Associates to that of Members—

Kenneth F. Campbell.

From the class of Associates to that of Associate Members—

Stanley Harris.
Guy S. Long.
William H. Ridpath.
Henry H. Wright.

Messrs. G. C. Allingham and G. Stannage were appointed scrutineers of the ballot for the election of new members, and, at the end of the meeting, the following were declared to have been duly elected:—

ELECTIONS.

Associate Members.

William Randall Elliott.
Manley Farrer.
Wilfred Hoult, B.Sc.
Basil Mortimer Iles.
David Macbeth.
Peter Scott Macduff.
Sidney Gilchrist Smith.
John Edwin Teasdel.
A. V. Wardrop.
Fred Williams.
Edgar Williamson.
Charles Herbert Wright.

Associate.

Charles Robert Gibson.

THE JOHN CRERAR LIBRARY

WHITTAKER'S
PRACTICAL HANDBOOKS

ALLSOP, F. C.	Electric Light Fitting. 5s.
BJÖRLING, P. R.	Pipes and Tubes. 3s. 6d. net.
BONNEY, G. E.	Induction Coils. 3s.
BOTTONE, S. R.	Electric Instrument Making. 3s. 6d.
,,	Electric Bells. 3s.
,,	Electro Motors. 3s.
,,	Galvanic Batteries. 5s.
,,	Wireless Telegraphy. 3s.
CRAPPER, E. H.	Electrical Measurements. 2s. 6d.
GRAY, J.	Electrical Influence Machines. 5s.
HAWKINS and WALLIS	The Dynamo, its Theory, Design and Manufacture. 15s.
HERBERT, T. E.	Telegraphy. 6s. 6d. net.
,,	Telephone System of the British Post Office. 3s. 6d.
HOBART, H. M.	Electric Motors. 12s. 6d. net.
LODGE, Sir O.	Lightning Conductors and Lightning Guards. 15s.
MAYCOCK, W. P.	Alternating-Current Circuit and Motor. 4s. 6d. net.
,,	Electricity and Magnetism. 2s. 6d.
,,	Electric Wiring, Fittings, Switches, and Lamps. 6s.
,,	Electric Lighting and Power Distribution. Vol. I., 6s.; Vol. II., 7s. 6d.
,,	Electric Wiring Tables. 3s. 6d.
MAZZOTTO, D.	Wireless Telegraphy and Telephony. 6s. net.
OWEN, W. C.	Telephone Lines and Methods of Constructing Them. 5s.
POOLE, J.	Practical Telephone Handbook. 6s. net.
RUSSELL, S. A.	Electric Light Cables. 10s. 6d.
SALOMONS, Sir D.	Management of Accumulators. 6s. net.
STILL, A.	Alternating Currents of Electricity and the Theory of Transformers. 5s.
TURNER and HOBART	Insulation of Electric Machines. 10s. 6d. net.
WHITTAKER'S Electrical Engineer's Pocket-Book. 3s. 6d. net.	

WHITTAKER & CO., 2 White Hart Street, LONDON, E.C.

TELEGRAPHY

A DETAILED EXPOSITION OF THE TELEGRAPH SYSTEM OF THE BRITISH POST OFFICE

BY

T. E. HERBERT, A.M. INST. E.E.

ENGINEER, POST OFFICE TELEGRAPHS

WITH 509 ILLUSTRATIONS

LONDON
WHITTAKER & CO.
2, WHITE HART ST., PATERNOSTER SQUARE, E.C.
AND 64 AND 66, FIFTH AVENUE, NEW YORK
1906

[*All rights reserved*]

L. C.

CHAPTER XII

THE HUGHES.

INTRODUCTORY.

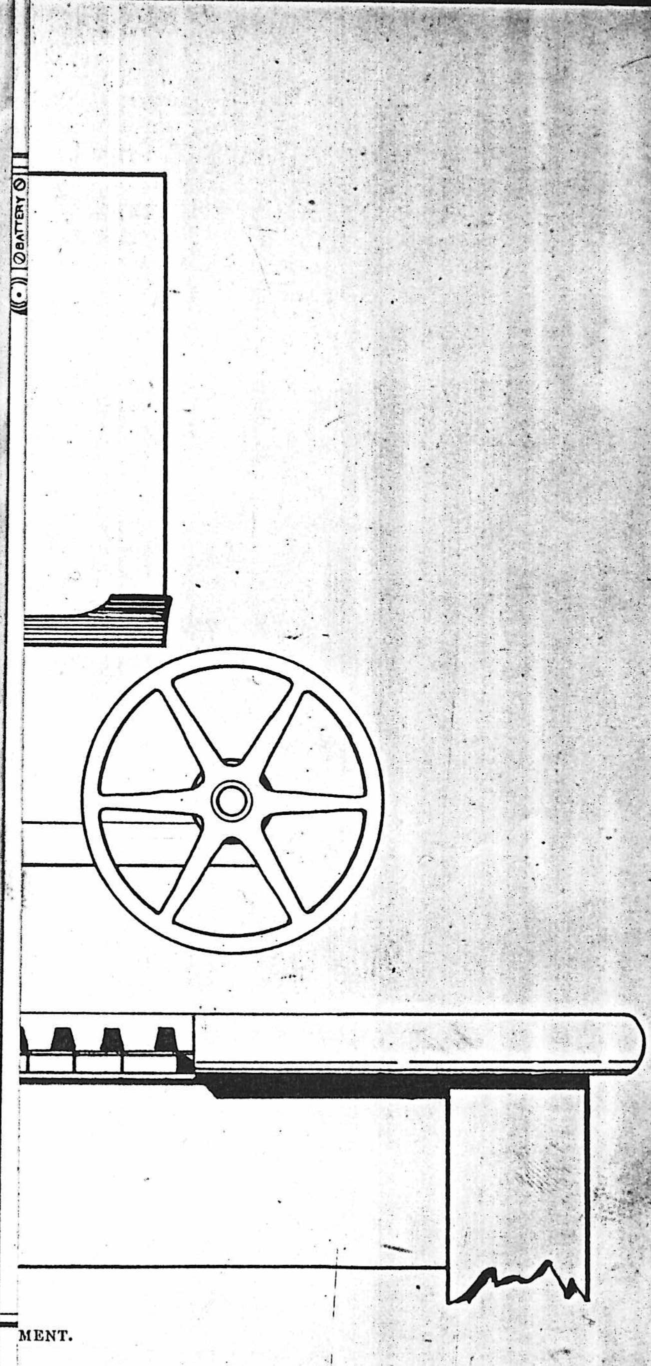
THE Hughes system, which may be classed under the heading of synchronous type-printing telegraphs, is largely mechanical in action and differs from all other systems in two most important particulars :—firstly, a single current only is required for each letter or character printed, and secondly, the type wheel revolves continuously and is not checked or stopped whilst a sign is being printed. The working currents are of equal duration, but are separated by unequal intervals of time.

Upon a cable circuit having a working speed of 40 words per minute with the Wheatstone apparatus and shunted condenser system, the Hughes may be worked at the highest speed at which it can be manipulated. The speed at which the instrument can be operated is also considerably in advance of the sounder, and in France the Hughes is employed in every case in which Morse working will not suffice to dispose of the traffic and in which high-speed working is not justified. In the British Post Office it is almost exclusively employed upon continental lines, where the gain in the working speed of the circuit amply justifies the costly apparatus and its somewhat expensive maintenance.

The general appearance of the apparatus and the disposition of its parts are illustrated in Figs. 190 and 191.

GENERAL PRINCIPLE.

The type wheel at one end of the circuit is exactly similar to that at the other end, revolving in complete synchronism, *i.e.* they not only revolve at precisely the

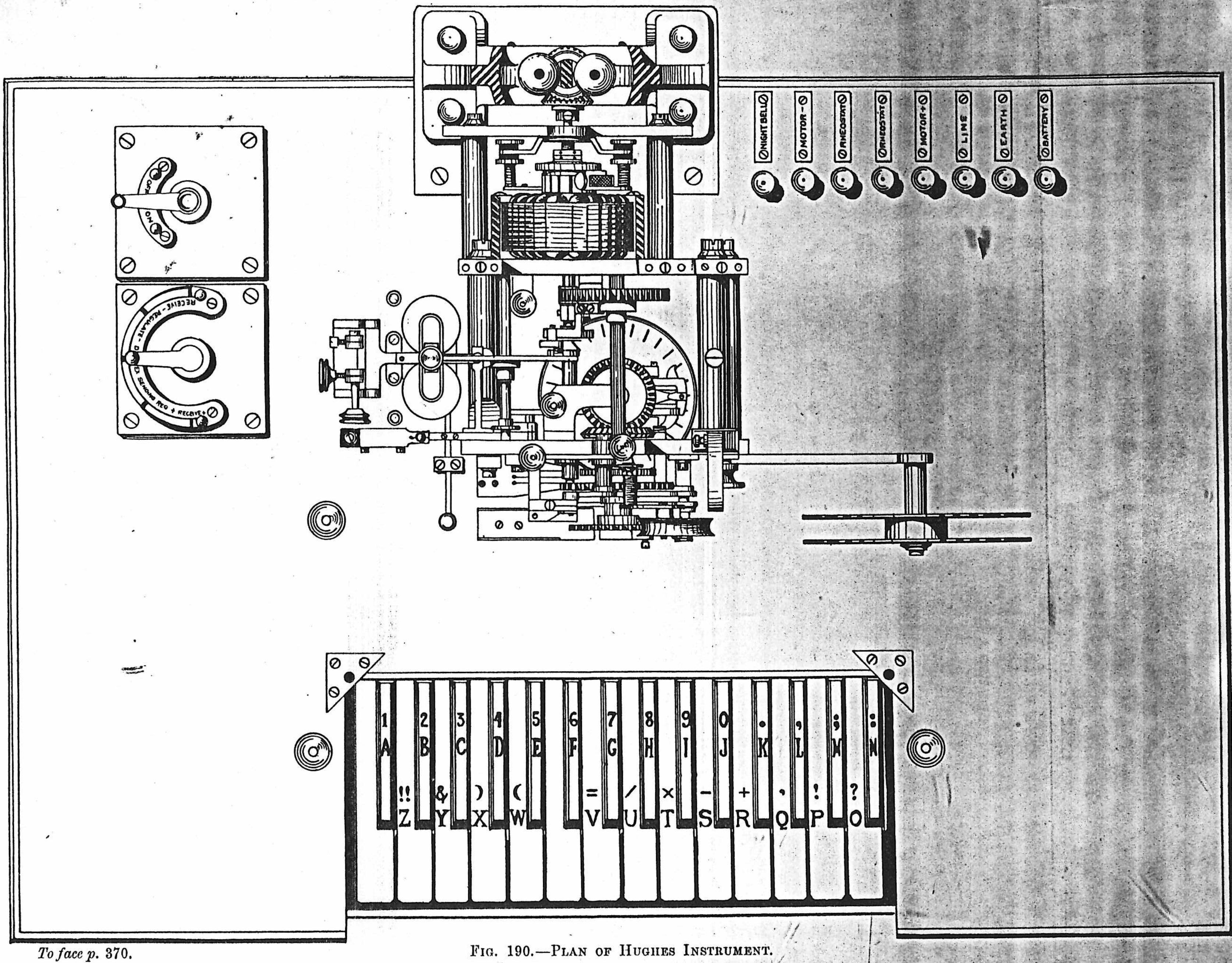


MENT.

r the head-
is largely
systems in
le current
inted, and
nd is not
ted. The
separated

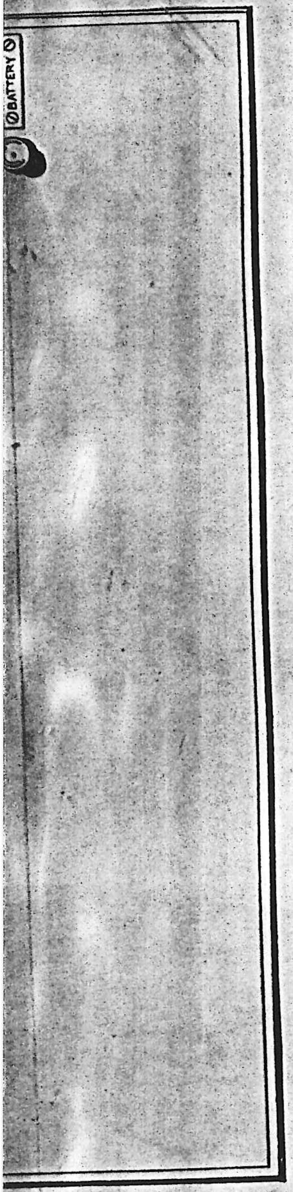
f 40 words
l shunted
he highest
l at which
lerably in
hes is em-
not suffice
vorking is
nost exclu-
e gain in
the costly
ce.
and the
190 and

is exactly
complete
cisely the



To face p. 370.

Fig. 190.—Plan of Hughes Instrument.



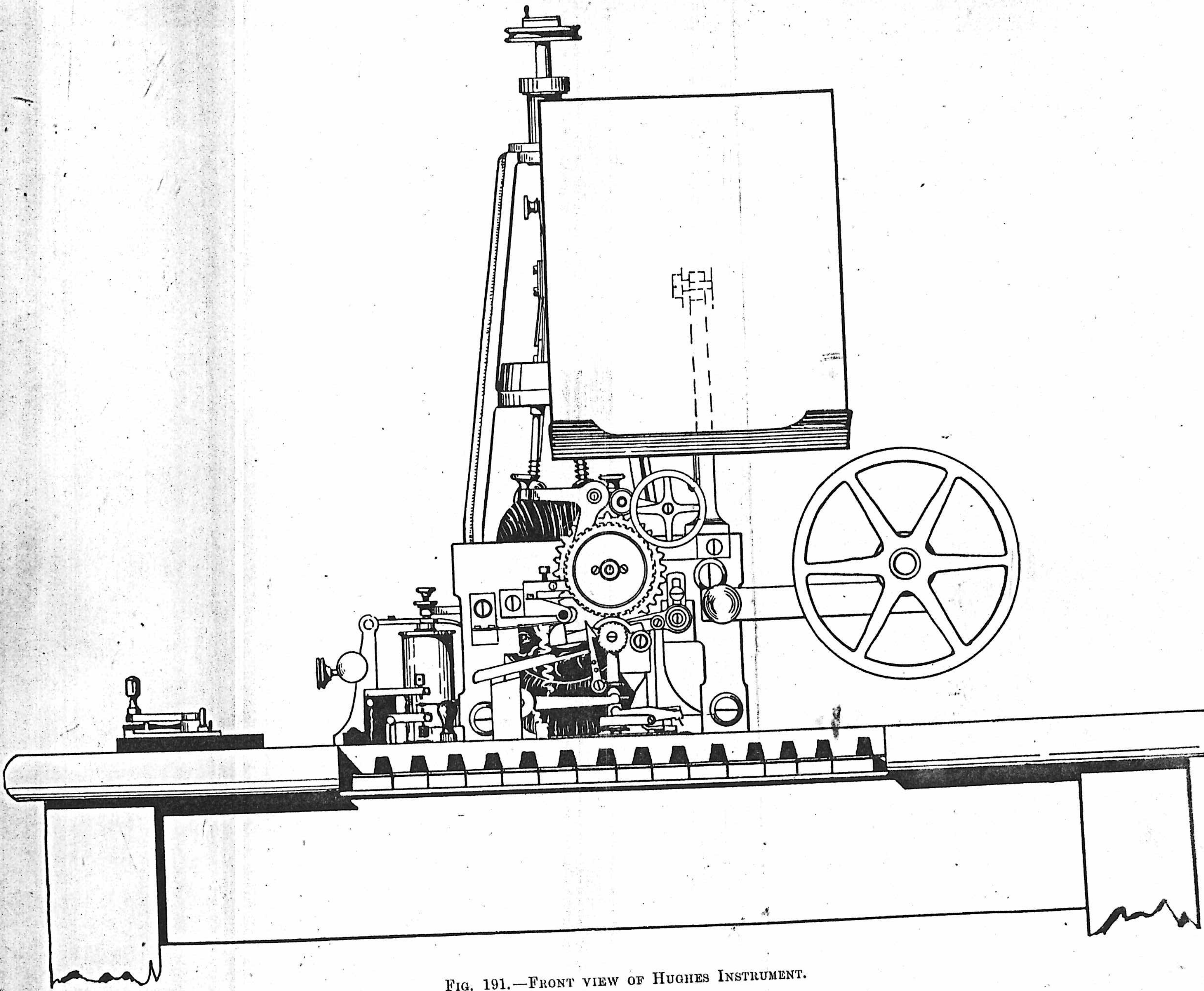


Fig. 191.—Front view of Hughes Instrument.

THE
JOHN CRERAR
LIBRARY.

THE JOHN CRERAR

same rate, but at any instant the same letter or sign upon each wheel occupies a position immediately above the tape. If at this moment the tapes at both ends are brought into contact with the type wheels the same sign will be printed at each end. The type wheel is inked by the inking wheel, which presses lightly upon it.

The transmitting portion of the apparatus consists of a keyboard furnished with 28 keys (see Fig. 190). Each of these keys is mechanically connected to a pin working in a radial slot in a circular plate. The chariot, which consists of a radial arm carrying a pivoted lever in connection with the stationary contact lever, sweeps over the pins. When a key is depressed the corresponding pin is raised and the end of the pivoted lever moves upwards when the chariot passes over it. This causes a current to be sent out to line. The home instrument is also actuated at the same instant by a projection upon the contact lever which raises the armature from the coils.

It will therefore be seen that a current may be sent out at any one of the 28 points in accordance with the position of the key which is depressed. It may, however, be pointed out that one, two, three, or even four currents may be sent out during one revolution of the chariot. This is, however, considered fully later.

The chariot and the type wheel are connected and revolve at precisely the same speed. Therefore each position of the chariot corresponds to the same position upon the type wheel. If the key marked "*R*" is depressed the letter "*R*" upon the type wheel will be immediately above the tape at the instant when the chariot is above the raised pin connected to the "*R*" key. As the pin is raised the chariot sends a short current out to line and at the same time mechanically operates the home apparatus. The result is that the letter *R* is printed at both stations.

The whole of the movements are controlled by three main axles which may be respectively designated the printing, the type wheel, and the chariot axles. The printing and type wheel axles are horizontal and parallel, whilst that of the chariot is vertical and is driven by means of an equal bevel wheel upon the type wheel axle.

The sole function of the current is to release the armature of the electromagnet, and this motion is made to link up the printing, driving and the printing axle proper for a single revolution. By mechanical devices the revolution of the printing axle effects :—

1. The synchronizing correction.
2. The printing of the character.
3. The progression of the paper.
4. The replacement of the armature.

Each current received or sent out brings about a complete revolution of the printing axle, which runs at seven times the speed of the type wheel and chariot. At the instant when the letter is printed the face of the particular type should be exactly parallel with the paper. Now, by means of a cam upon the printing axle, the position of the type wheel is adjusted every time a letter is printed. Since at least one and sometimes three or four characters are recorded during each revolution the frequency of this mechanical correction is more than sufficient to ensure absolute synchronism between the two instruments. An electro motor controlled by a rheostat provides the motive power for rotating the mechanism whilst a suitable governor determines the speed at which it runs. As will be seen later, it is by means of this governor that the speed of the instrument is adjusted to be in unison with the apparatus at the distant end. The functions named under 2, 3, and 4 require no explanation.

Having dealt with the general principle of the instrument, it will now be necessary to consider the details of the mechanism. These will not, however, prove very intelligible unless the reader has grasped the fundamental principles which have just been stated.

The Hughes Electromagnet.

Two coils of wire are wound upon the soft iron cores attached to the poles of a powerful compound magnet (Fig. 192). The armature, which is also of soft iron, is normally attracted to the cores, but this attraction is opposed by two antagonistic springs. The armature is, however, held down by the downward attraction of the magnet which is greater than the upward pull of the springs. If, for the sake of illustration, the force of attraction is 100 units and the upward pull of the spring is 92, the armature is held down by a force equal to 8 units. The passage of a current through the coils in such a direction as to oppose the magnetism of the cores will cause the armature to be released immediately the attraction is reduced below 92 units. The armature will then fly off with the full force of the spring, *i. e.* with a force of 92 units. In this way the reduction of the attraction by anything over 8 units brings into play the full force of the spring. The upward movement of the armature serves to bring into operation the various mechanical portions of the apparatus which synchronize the two type wheels, print the letter, move the paper forward, and replace the armature. The Hughes is therefore a directly, and not a relay, worked instrument.

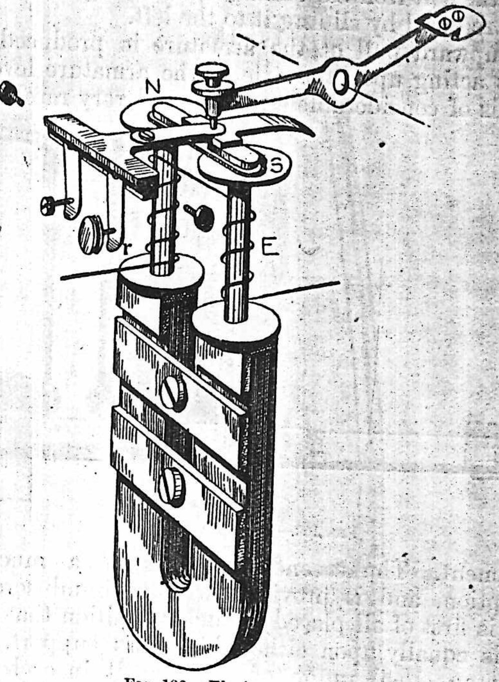


Fig. 192.—Electromagnet.

The value of the attraction between the cores and the armature may be varied by sliding the soft iron bar to right or left as required. The bar (Fig. 193) forms a conducting path for the lines of force, thus reducing the number flowing through the armature, and hence the force of the attraction. When the lever is pushed well over to the right it is evident that the attraction will be least, whilst it will be gradually increased as the volume of that part of the soft iron bar resting upon the right-hand magnet limb is reduced by sliding it to the left.

The upward pull of the armature is produced by two springs acting upon the axle of the armature lever. One spring is of considerable strength, and very rarely requires adjustment. The second spring is of a much lighter description, and is provided with a thumb-screw. This screw is first of all placed in such a position that its thread extends equally upon either side of its support, thus providing an equal range of adjustment in each direction. The permanent magnet armature is then adjusted until the slightest vibration will serve to release the armature. The adjusting screw is then given two turns in such a direction as to reduce the force tending to raise the armature. This provides ample working margin without unduly decreasing the sensitiveness of the instrument.

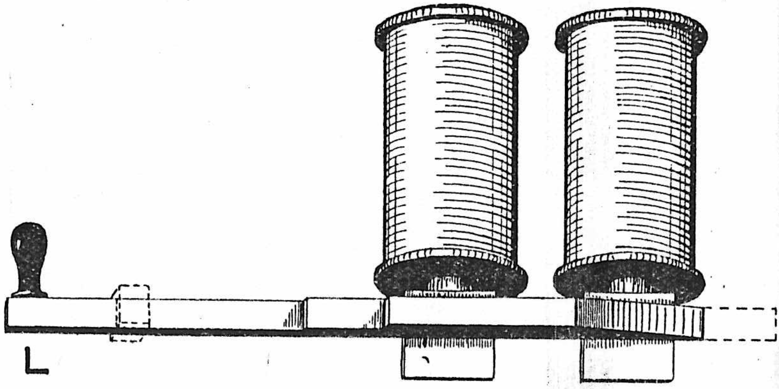


FIG. 193.—Magnetic adjustment.

The coils are differentially wound, and have a resistance of 500^{ω} each, or 1000^{ω} in series.

It should also be pointed out that the position of the electromagnet is adjustable, so as to ensure that the armature shall lie evenly upon the centre of the polar projections.

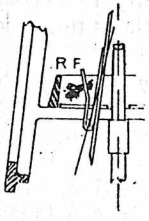


FIG. 195.—Brake on the governor.

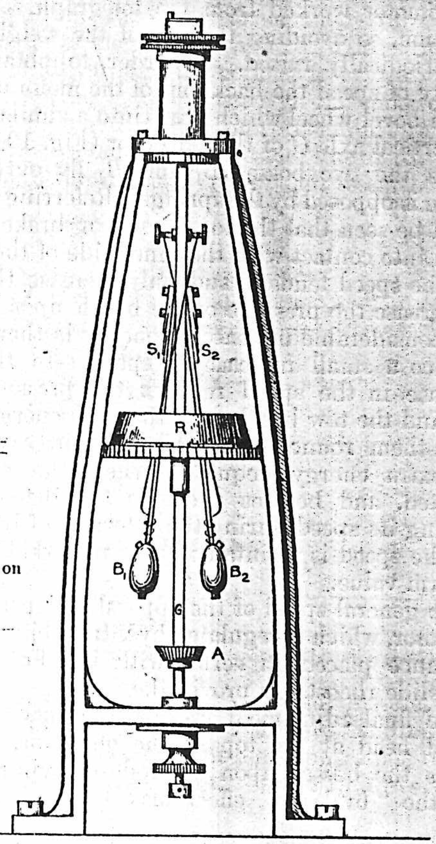


FIG. 194.—View of governor.

A piece of slip is placed between the armature and the cores, and is secured in position by suitable clips, to prevent "sticking" and to render the action more rapid.

Motive Power and Governor.

The latest form of Hughes instrument is driven by an electromotor worked from the telegraph secondary cell installation, so avoiding the use of the weight which had to be periodically raised. In order to obtain perfect uniformity of speed the back end of the motor axle is furnished with a bevel wheel which gears into a similar wheel *A* upon the vertical axle *G* of the governor (Fig. 194). As the axle rotates the two bosses B_1 and B_2 fly outwards, but this motion is opposed by the springs. Referring now to Fig. 195, it will be seen that the tow brush or brake upon each rod comes into contact with the inner side of the ring *R*.

If the speed tends to suddenly increase, the bosses B_1 and B_2 increase the pressure of the brush upon the ring, and a very considerable increase of energy is therefore needed to produce a small increase of speed. In the same way a decrease in the speed reduces the pressure between the ring and the tow brushes, so that less energy is required to drive them round. This action secures the provision of the extra energy required when the printing axle is operated, and besides prevents the instrument from increasing its speed during the intervals of inaction. In this way the speed is maintained at a remarkably constant and uniform value.

The general speed of the apparatus depends upon that of the motor, which is regulated by introducing or withdrawing resistance placed in series with it. For this purpose a 100^{ω} slide rheostat is provided.

The final adjustment is, however, made by turning the milled head at the top of the governor, which raises or lowers the bosses upon the rods carrying them. In this way the "braking" effect may be varied to a nicety.

Earthing of the Line immediately the Armature Rises.

In order to obtain the maximum sensitiveness it is essential that the current shall only rise to a value sufficient to release the armature. The passage of a large current would produce trouble due to residual magnetism, as the opposing magnetizing force exerted by the current would not totally

disappear. In that case, to keep the armature upon the cores when replaced, the adjustment would have to be of an extremely coarse character.

When the armature *a* rises and comes into contact with the lever (Fig. 196) the line is earthed, thus short-circuiting the coils of the electromagnet. The path of the current is first of all through the contact lever, through the stud *K* and the spring *S*, and so through the coils to earth. The armature *a* rises and strikes sharply against the lever. Immediately this contact is made, the line path of the current is through the contact lever *c* viâ *a* to earth.

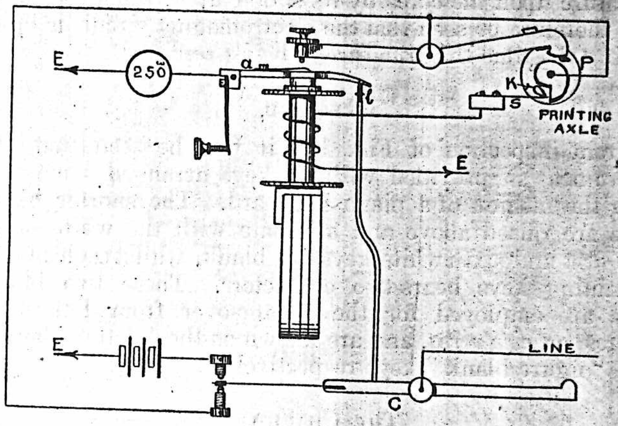


Fig. 196.—Skeleton connections and arrangement of Hughes apparatus.

The connection of the line direct to earth immediately the instrument has been actuated greatly facilitates the discharge of any charge or current remaining upon the line, and therefore increases the length of the line over which the system can be worked.

Electromagnet Disconnected whilst the Armature is Replaced.

The electromagnet circuit is broken whilst the armature is replaced upon the cores in order to avoid ill-effects from the E.M.F. of self-induction which is thereby generated. This induced E.M.F. is in the same direction as the current which caused the armature to rise. Since the electromagnet circuit is open there is no path for the E.M.F. to act through, and consequently no effect is produced. Were a path existing the armature would fly off the cores, due to the demagnetizing force of the self-induction discharge.

Whenever a letter is printed the cam *P* upon the printing axle makes a complete revolution. It carries with it the pin *k*, thus breaking the contact existing between *K* and the spring *S*. This disconnects the electromagnet until the cam *K* has resumed its normal position. But the cam *P* has, during the earlier part of its revolution, replaced the armature upon the cores by its action upon the lever *l*. It will therefore be seen that the electromagnet circuit is open during the time the armature is being replaced.

KEYBOARD.

From inspection of Fig. 190 it will be seen that the instrument is provided with 28 keys arranged somewhat after the fashion of a piano keyboard. The shorter black keys are raised above and alternate with the white ones. The first and sixth white keys are blank, whilst each of the remaining keys bears two characters. These two blank keys are employed for the change-over from letters to figures, or *vice versa*, and are known as the "letter blank" and "figure blank" keys respectively.

THE CHARIOT.

Twenty-eight letter pins, which may be raised by their respective keys, normally rest within the radial slots upon the circular plate shown in plan in Fig. 199. These pins are of the form depicted in Fig. 197, and are normally held in position by the spiral springs attached to them. The depression of a key raises the relative pin above the pin plate, as indicated by the dotted outline at *M*.

The chariot revolves with the type wheel axle to which it is geared by equal bevel wheels and maintained in intimate contact by the upward pressure of the spiral spring *S* (in compression). The chariot axle *A* carries a radial arm *C* upon the end of which the rocking lever *D* is pivoted. The outer end of this lever is directly above the pins in the key plate, whilst the inner end is connected to the lipped

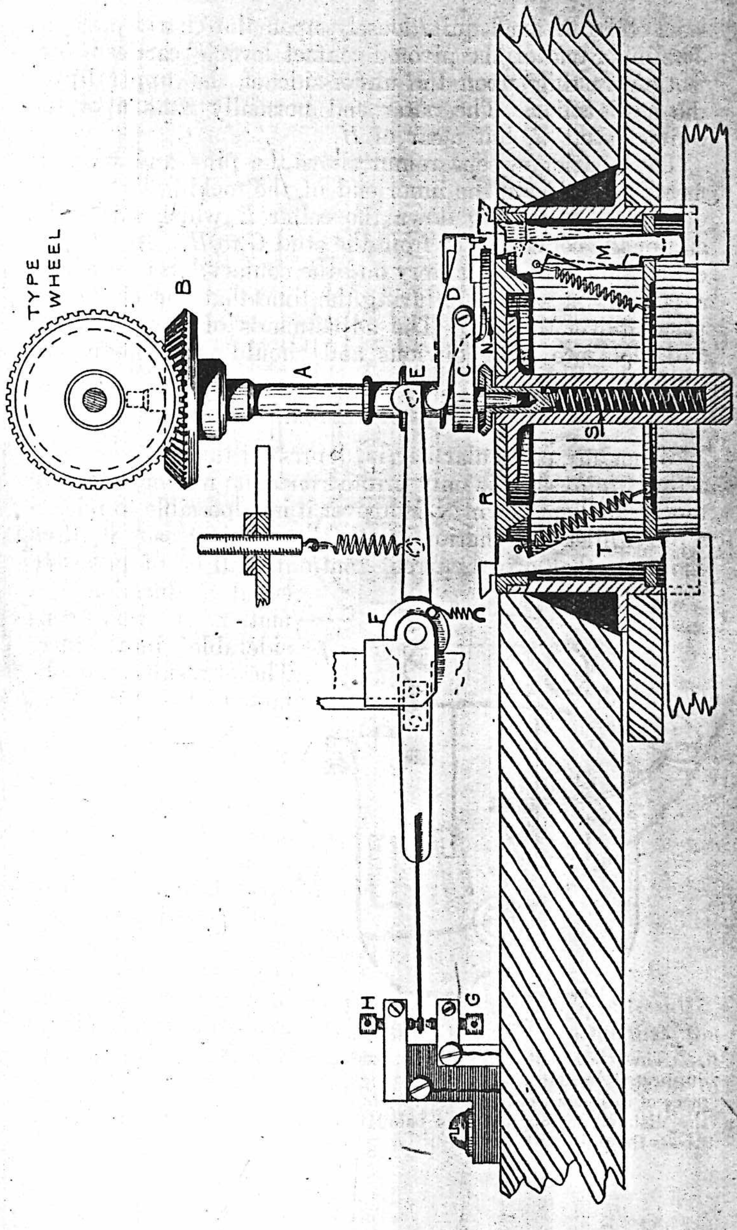


FIG. 197.—Chariot, contact maker and pins.

steel collar *E* fixed quite loosely upon the chariot axle *A*. The inner end of the pivoted contact lever *F* carries a projection resting upon the under-side of the upper lip of the steel collar. The outer end normally rests upon the contact stud *G*, but clear of *H*.

The chariot sweeps round above the pins, and when it meets a raised pin the inner end of the rocking lever *D* is depressed, so pulling down the collar *E* which raises the end of the contact lever from the stud *G* to *H*. As *H* is in connection with the battery and the contact lever is to line a current is sent out during the time that the chariot is passing over the pin. The adjustments of these contacts and slots are quite obvious and should need no further comment.

THE REJECTOR.

When any particular key is depressed the letter or character it represents is only printed once, no matter how long the key is kept down.* Moreover it is impossible to release a pin whilst the chariot is actually passing over it, thus ensuring that every current sent out shall be of precisely equal duration — a matter of very considerable importance. These results are obtained by the "rejector," so called on account of its action in rejecting a pin over which it has passed once without the key being released. It is carried upon the arm of the chariot and consists of a steel plate *N* of the shape illustrated in Fig. 198. In order to prevent the breakage

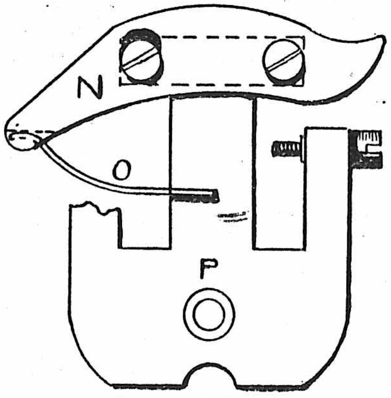


FIG. 198.—Rejector.

---

* This statement is not strictly true in practice, since a letter may be duplicated by depressing key too lightly (see page 393). By forcing a piece of cardboard between the letters *G* and *U* a continual call is given to the distant station, currents being transmitted every time the chariot passes the pins.

of any pin which happens to stick the forward portion of the plate is secured by a screw passing through a slot against the inner end of which it is normally held by the spring *O*. This gives the plate a certain amount of play.

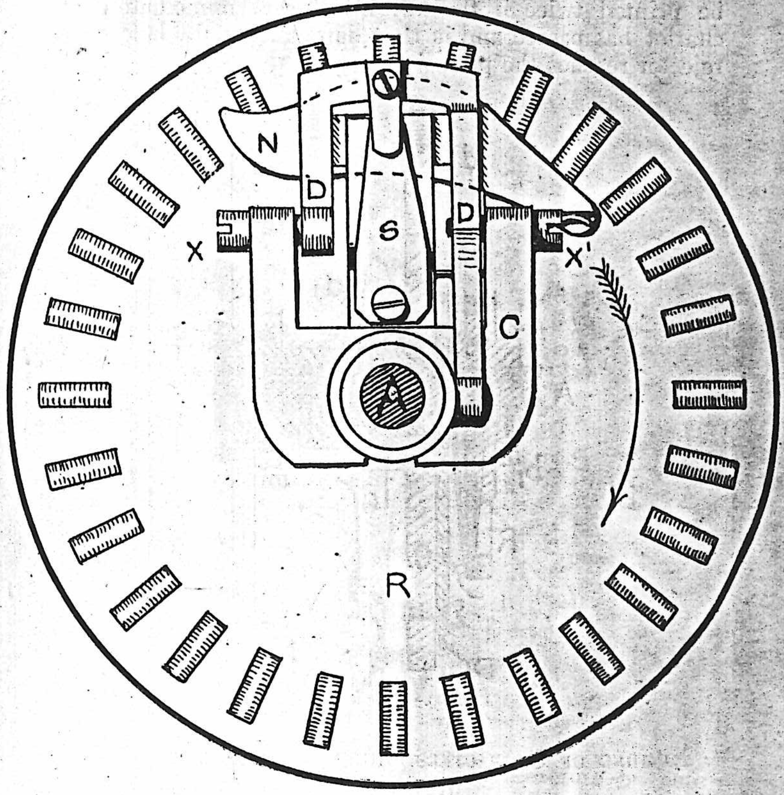


FIG. 199.—Pin plate and rejector.

Referring now to Fig. 197, which has been lettered to accord with Figs. 198 and 199, it will be seen that the forked chariot arm *C* carries the contact arm *D*, beneath which is the rejector. Immediately the forward portion of the rejector meets a raised pin, that pin is held until the rejector has passed it, during which time the release of the key in connection with it does not permit the pin to fall back. When the back end of the rejector has passed the pin, it is already pushed back beyond the reach of the contact arm, and therefore when the chariot next passes a second current is not sent out. The letter may, of course, be printed twice if the key is released immediately the chariot has passed and is then depressed again before the rejector reaches the pin.

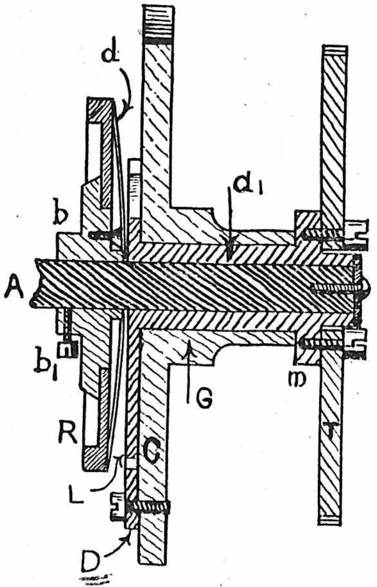


Fig. 200.—Type wheel axle.

Number of Characters which can be Printed per Revolution.

The mechanical inertia limits the number of characters which can be printed during a single revolution of the type wheel. After the depression of the letter blank key, the next letter which can be printed is *E*, followed by *J*, *O*, and *T*, *i.e.* every fifth letter. The chariot, however, covers three pins only in order to provide a working margin.

The Type Wheel Axle.

The type wheel axle is driven by the motor and transmits the motion to the chariot by means of bevel wheels. It carries three wheels, (1) the type wheel, (2) the correction wheel, and (3) the ratchet wheel. The ratchet wheel *R* (Figs. 200 and 201) is held in contact with the collet upon which it is mounted by the dished disc *d*. The collet is secured to the axle by the screw b_1, but the ratchet wheel is only friction-tight upon it, and may therefore be held stationary whilst the axle continues to revolve. The ratchet wheel (Fig. 201) is engaged by the pawl *F* fixed to the face of the correcting wheel *C*. By means of the pawl *P* the motion of the correcting wheel is transmitted through the lever *L* to the tube d_1 which is rigidly connected to the type wheel *T* (Fig. 200). This tube passes over the type wheel axle, but is sufficiently loose upon it to prevent the motion of the axle being communicated. Now the correcting

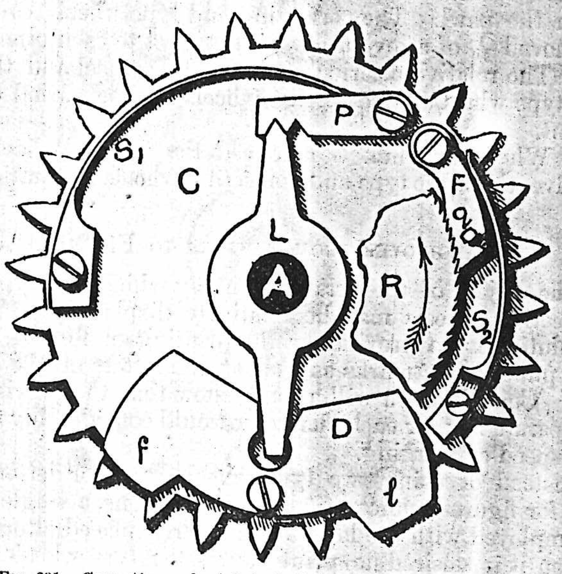


Fig. 201.—Correcting and ratchet wheels; type wheel printing letters.

wheel is carried upon a second tube which fits loosely over the type-wheel tube. It will therefore be seen that :—

1. If the correcting wheel is held the type wheel axle may continue to revolve, whilst the ratchet, correcting, and type wheels, are stationary.

2. Since the ratchet wheel drives the type wheel through the pawl upon the correcting wheel and the lever upon the type wheel tube, the type wheel may be displaced with respect to the correcting wheel to an extent which is limited by the two positions which the lever may occupy upon the pawl. The correcting and type wheels can only be moved $\frac{1}{56}$ of a revolution with respect to each other.

3. The relative position of the ratchet wheel and that of the type wheel and correcting wheels can be varied to any extent.

4. When the click *G* is raised the ratchet wheel may revolve whilst the type and correcting wheels are stationary.

CHANGE-OVER FROM LETTERS TO FIGURES.

The object of the arrangement by which the type and correcting wheels may be relatively displaced by $\frac{1}{56}$ of a revolution is to provide for the printing of figures, signs, and punctuation marks as well as the letters of the alphabet. Consideration will at once show that the provision of a separate key for each character would considerably reduce the speed of working.

Instead of using two type wheels, one for letters and one for figures, punctuation and other signs, a single wheel is employed with the letters and figures placed alternately. When it is desired to print figures the type wheel is displaced to the extent of $\frac{1}{56}$ of a revolution. Each unit of time, equal to $\frac{1}{28}$ of a revolution of the chariot, which elapses allows the type wheel to turn through $\frac{1}{28}$ of a revolution, and thus the alternate characters are not printed. For instance, in printing "Jot" the "?" before "o" and the "×" before "t" are passed before the respective currents arrive. With the currents arriving with the same time intervals, but with the type wheel displaced $\frac{1}{56}$ revolution, the characters printed would be "0 (figure, not the letter)? ×." The 56 characters and spaces upon the type wheel are in order as follows :—

Blank Blank 1 *A* 2 *B* 3 *C* 4 *D* 5 *E* 6 *F* 7 *G* 8 *H* 9 *I* 0 *J* . *K* , *L* ; *M* : *N* ? *O* ! *P* ' *Q* + *R* – *S* × *T* / *U* = *V* Blank Blank (*W*) *X* & *Y* " *Z*

It will be shown later that the position of the type wheel is corrected every time the electromagnet is actuated. This is accomplished by the correcting cam which forces its way between two successive teeth upon the correcting wheel. Now, at two points upon the type wheel blank spaces are left, whilst either of the corresponding positions upon the correcting wheel may be occupied by the projecting portions of the "figure-changing lever." Referring to Fig. 201 it will be seen that the depression of the first or letter blank key will cause the cam to pass between the teeth opposite to *f*. As there is no character upon the type wheel at the point which is directly above the paper, a space is produced. If, however, the correcting wheel had moved so that the right-hand portion of the change-over lever was opposite the correcting cam, then this cam in

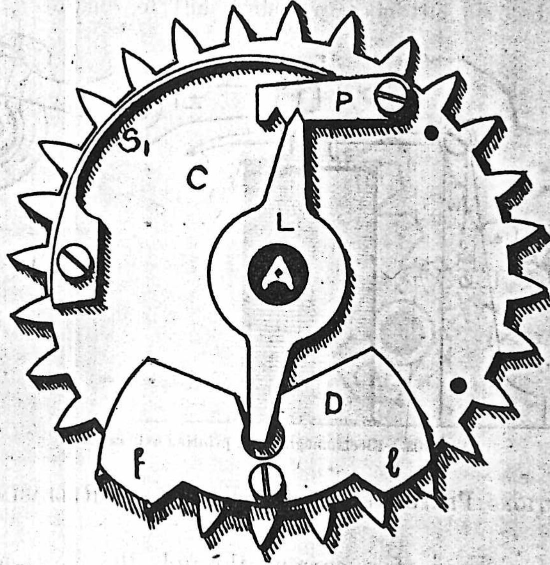


FIG. 202.—Correcting wheel. Change-over from letters to figures.

passing between the teeth would move the figure-changing lever upwards, thus causing the lever to engage the backward notch upon the pawl. This would be the case if the figure blank key was depressed. As already stated this displaces the type and correcting wheels by $\frac{1}{50}$ of a revolution, so changing over from letters to figures. The change back to letters would of course be made by depressing the letter blank key, when the correcting cam would reverse the position of the cross lever in the notches of the pawl.

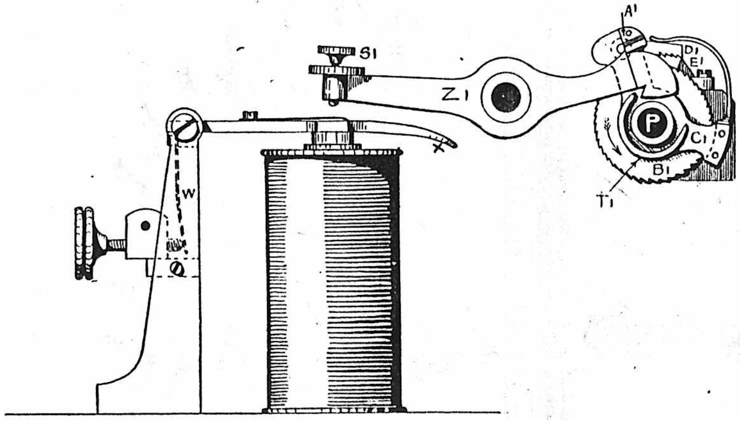


Fig. 203.—Electromagnet and printing axle ratchet.

Functions Performed as the Result of Releasing the Armature.

The passage of a current through the electromagnet releases the armature, and this upward movement is employed to bring about a mechanical connection between the printing driving axle and the printing axle proper. This connection causes the printing axle to make one complete revolution, and to disengage, *i.e.* every current produces a single revolution of the printing axle. By means of suitable cams and other devices in connection with this axle the following effects are produced :—

1. The position of the type wheel is corrected, and by the same action the change from letters to figures or *vice versa* is effected when required.

2. The slip is sharply brought into contact with the type wheel, so printing the letter.
3. The paper is moved forward.
4. The armature is replaced upon the electromagnet.
5. The electromagnet is disconnected until the armature has been replaced.

Printing Axle Entrained.

The impact of the armature upon the pivoted detent

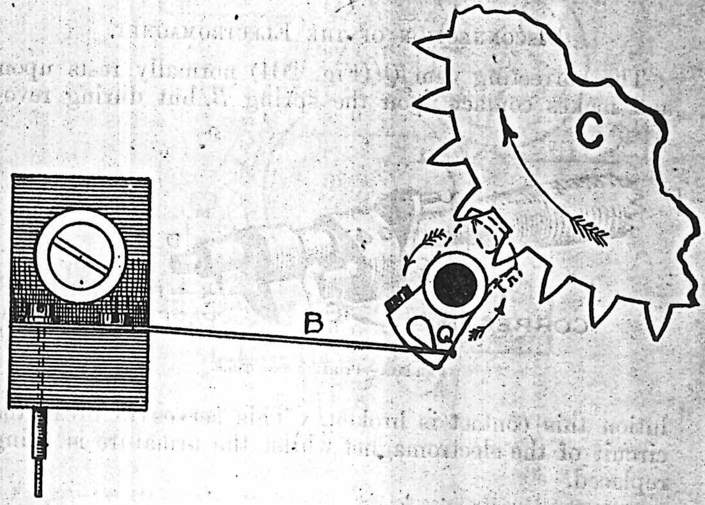


Fig. 204.—Correcting cam and disconnection of the electromagnet.

lever Z^1 (Fig. 203), depresses the further end of the lever, thus releasing the click D^1 which descends upon and engages with the continuously revolving ratchet wheel B^1. In this way the printing axle is entrained, but when the click has travelled about $\frac{7}{8}$ of the revolution it reaches the inclined plane E^1. The momentum it has acquired is sufficient to cause it to ride up the inclined plane, so disengaging from the ratchet wheel and finally bringing it back to its normal position of rest against the projecting portion of the detent lever.

REPLACEMENT OF THE ARMATURE.

Upon the central portion of the click and click-spring arms an eccentric T_1 projects sufficiently far to engage the detent lever during revolution. It will therefore be seen that the eccentric raises the detent lever, and by means of the screw S^1 replaces the armature upon the cores. It will also be observed that the detent lever is in its normal position before the click disengages, and that it is therefore impossible for the click to over-shoot its normal position.

DISCONNECTION OF THE ELECTROMAGNET.

The correcting cam Q (Fig. 204) normally rests upon and makes contact upon the spring B, but during revolution this contact is broken. This serves to break the circuit of the electromagnet whilst the armature is being replaced.

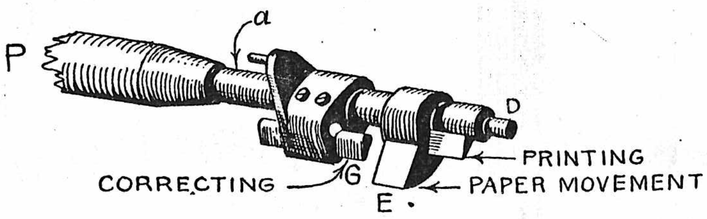


FIG. 205.—Printing axle cams.

PRINTING AXLE CAMS.

The other functions performed by the printing axle are effected by three cams attached to the printing axle. They are clearly shown in Fig. 205, and the function of each suitably indicated.

CORRECTION FOR SYNCHRONISM.

The steel correcting cam Q, which is carried round by the printing axle engages with the correcting wheel, and is so adjusted that when the type wheel is in its correct position, *i.e.* when the letter to be printed is exactly parallel with and wholly in contact with the tape, it lies between the teeth of the correcting wheel as shown by the dotted lines in Fig. 204. If the wheel is slightly behind the position it should occupy, the cam strikes the forward tooth, and so pulls the wheel round to its correct position, always provided that the actual and the correct positions do not differ by more than half a tooth. In a similar way the cam pulls the wheel back to the correct position if the wheel is in advance.

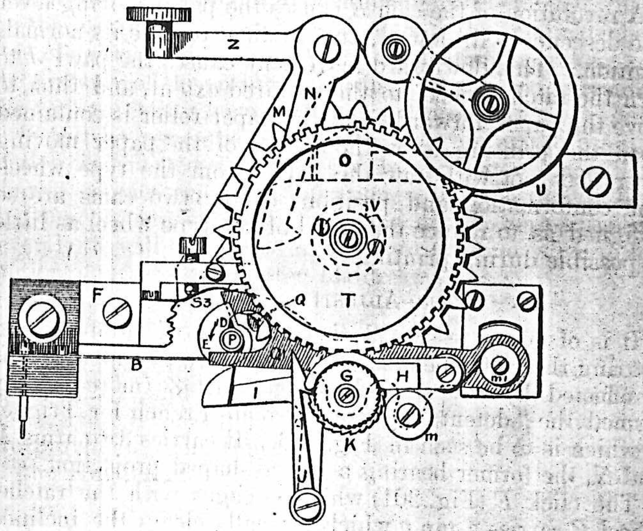


FIG. 206.—General figure of type, correcting and inking wheels and printing lever.

The correcting cam is of tempered steel, as also is the correcting wheel. The cam can readily be removed and another substituted whenever signs of wear appear.

PAPER MOVEMENT.

Referring to Fig. 206 it will be seen that the printing lever Q_1, pivoted at m_1 carries a second lever I, known as the paper-moving lever. The slip is carried under m over G, upon which it is pressed by the fork H. In the position shown the paper is in contact with the type wheel due to the cam D having completed rather more than half a revolution. This cam, then, working in the forked end of the printing lever raises the paper against the type wheel whenever the printing axle makes a revolution. It should also be noticed that at the moment of printing the correcting cam is exactly midway between two successive teeth upon the correcting wheel. As it is equal in length to the distance between the teeth, the type wheel is steadied and this no doubt conduces towards the clearness of printing.

A revolution of the cam *E* causes the paper-moving lever *I* to descend to its lowest, and to then resume its normal, position. This downward movement causes the pawl *J* to turn the ratchet wheel to the required extent, and thus to move the paper forward. As the paper roller is contained upon the printing lever the motion of the paper moving lever does not withdraw the paper from the type wheel. The conformation and positions of the two cams are so designed as to reduce the speed of the type wheel as little as possible during printing.

ZERO-ADJUSTING LEVER.

It is of course essential that a means of stopping and starting the instruments at zero should be provided. This is effected by the zero-adjusting lever *Z* (more usually termed the "detent")—origin *Detente* French for Trigger—which is to be seen in Fig. 206. It carries two arms *M* and *N*, the former bearing a wedge-shaped projection.

The click *F* (Fig. 201) which engages with the ratchet wheel *R* carries a pin *q* which normally clears the inclined plane *o* (Fig. 206) carried upon the spring *U*. But when the zero-adjusting lever is depressed the wedge-shaped projection of the arm *M* moves the plane towards the correcting wheel, so that the pin comes into contact with, and rides up, the inclined plane, finally resting in the notch at its apex. This raises the click *F* (Fig. 201) from the ratchet wheel, so disconnecting the correcting and type wheels. The momentum which the combined type and correcting wheels have acquired is sufficient to carry them to such a position that the projection upon the arm *N* (Fig. 206) banks against the forward side of the notch *V*, and the pressure upon the adjusting lever is sufficient to complete the movement already described.

Now the wedge and the inclined plane lock together by means of a suitable catch, and the zero-adjusting key therefore remains depressed. At this point the letter blank portion of the type wheel stands directly above the paper.

If now the letter blank key is depressed a current will be sent out immediately the chariot passes over the letter blank pin. This current causes the printing axle to revolve, thus forcing the correcting cam between the teeth of the correcting wheel, thus moving it forward sufficiently far to permit the click *F* to fall upon and engage the ratchet wheel. As the locking between the arm *M* and the inclined plane *O* is of a very slight character the connection is broken, and the pressure of the spring *U* acting upon the wedge restores the zero-adjusting lever to its normal position.

It will be remembered that the printing at the sending station is effected mechanically by an extension of the chariot contact arm, and reflection will show that if both instruments are stopped by means of the zero-adjusting lever both will be started at the zero position when either station depresses the letter blank key.

CONNECTIONS.

The full connections of a Hughes instrument are depicted in Fig. 207, and it will be noticed that two switches, respectively termed the "Hughes" and "motor" switches, are provided. The functions of each of the five positions of the Hughes switch are shown in the following table.

HUGHES SWITCH.

Position of Switch.	Functions of Switch in each position.
1. "Receive – " 5. "Receive + "	Determines the direction in which the coils of the electromagnet are connected between line and earth.
2. "Regulate – " 4. "Regulate + "	Disconnects the coils of the electromagnet and earths the line through the 250^{ω} resistance coil.
5 "Duplex sending"	Disconnects the coils of the electromagnet and changes the connections so that the line is earthed after each current has been sent out.

When the direction of the current received is such as to increase, instead of to reduce, the magnetism of the electromagnet cores, the Hughes switch at the receiving end is turned from position 1 to position 5 or *vice versa.* Reflection will show that the provision of this reversing arrangement is preferable to a battery reversing switch, since the receiving office would have to notify the sender that his battery must be reversed.

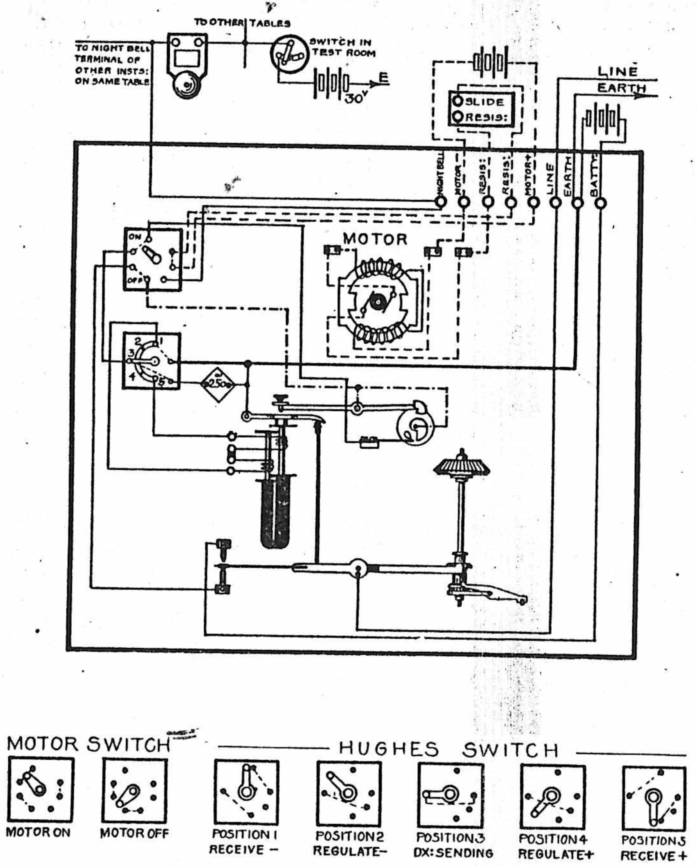


FIG. 207.—Connections of a Hughes set.

The two positions marked "regulate" produce identical connections. The coils are disconnected and the spring in connection with the correcting cam is connected to the armature. In this way a path to earth through the 250ω coil is provided. If the armature is upon the cores the path is through the correcting cam and spring, but if raised then the path is viâ the armature.

The "duplex sending" position is dealt with under duplex working.

The motor switch, in the "on" position, joins up the electro-motor. In the second position the connections are changed so that the rising of the armature connects the "night bell" terminal to earth. In this way calls are registered during the hours when the continuous attendance of an officer at the circuit is not necessary.

The remaining connections are quite obvious and call for no further comment.

MANIPULATION.

The actual manipulation of a Hughes instrument needs a very considerable amount of experience. Firstly, it is necessary to acquire the correct "touch," since by pressing the keys too heavily the pin is thrust out of its orifice, and the chariot passes over without sending out a current. Insufficient pressure usually results in some letters being missed and others duplicated. Secondly, it is essential that characters should be printed as frequently as possible, and the chariot should never be allowed to make a complete revolution without one or more signals being sent out. The operator feels the chariot pass over the raised pin because the rejector pushes the pin outwards, and thereby allows the key in connection with it to slightly descend. In this way the sender is apprized of transmission of each and every signal. The more frequently characters are printed the more often is the type wheel corrected for synchronism, and the more perfect is the accord between the instruments. So soon as the sender begins to miss revolutions there is risk of the instruments running out, and it may be said that until a learner is able to finger the keys accurately at such a speed as never to miss a revolution it is impossible for him to work a circuit.

Conventional Signals.

In the practical operation of the apparatus the following conventional signals are employed :—

Signal.	Indicates.	Reply Signal.
**Blank* N *Blank* N *Blank*	Call	*Blank* N *Blank* N *Blank.*
**Blank Blank*	All right. Yes. Understand.	
+	End of message.	
R (followed by figure)	Number of messages received in last batch.	
— — (word) — —	Word or words between underlined.	
**Blank* E J O T *Blank* E J O T	Wish to test for loss of speed	*Blank* E J O T repeatedly.
**Blank* I N S *Blank* I N S	Wish to regulate magnet	*Blank* I N S repeatedly.
N *Blank* N *Blank*	Correction, rub out.	
*Blank I T Blank I T	Wish to test synchronism	*Blanks* repeatedly.
I N	Used to interrupt or stop the sender	Both stations set their instruments to zero.

* These signals should be read by sound.

Preparations before Connecting the Instrument to Line.

Before placing the apparatus in connection with the line the instrument should first of all be oiled, care being taken to use the oil sparingly. The contacts should next be examined and cleaned if necessary—all paper, dust, etc., should be carefully removed. In fact absolute cleanliness is essential.

The electromagnet should now be adjusted as previously described upon page 374, and finally the apparatus should be tested for loss of speed. Firstly by printing Blank *I N S* in one revolution and then Blank *E J O T*, each set being continuously repeated several times. If these signals are printed satisfactorily the apparatus may be connected to the circuit, but, if not, it is necessary to trace and remedy the

defect. This may be due to a variety of causes, for instance, it would be produced by the rejector not clearing the pins, abnormal friction at several points, etc., etc. There should, however, be little or no difficulty in locating the seat of the trouble.

Here it may be well to point out that signals should never be sent until the apparatus has attained its full speed, since damage to the ratchet wheel and its click would inevitably result.

Adjustment for Equality of Speed.

The instruments having been connected to the circuit at each end it is first of all necessary to adjust their speeds so that they shall correspond as nearly as possible. This is accomplished by receiving a series of "blanks." If the home instrument is running faster than the distant one it will be obvious that letters will be printed in the order *A B C D E*, etc., instead of the blanks which should be recorded. But should the home instrument be running too slowly *Z Y X W V* will be printed. This adjustment is effected by means of the thumb-screw upon the governor which raises or lowers the "bobs," so respectively increasing or decreasing the speed as desired.

The next adjustment is made as follows :—The distant station sends out a blank at every revolution of the chariot. At the receiving end the current is cut off for an interval of about five revolutions, so assuring that the speeds of the two type wheels differ by less than half a tooth in the five revolutions. Finally the current is cut off for ten revolutions, and, if the blanks continue to be received correctly, the instruments are in sufficiently satisfactory accord for practical working.

The final adjustment of the electromagnet is made during the reception of the conventional signals "Blank *I N S.*" This adjustment is usually of a very fine character and is made by means of the screw in connection with the antagonistic spring. The sliding keeper upon the electromagnet should not be employed as the alterations produced are far too large. It should be borne in mind that the adjustment of the electromagnet is of vital importance, and